FACULDADE DE CIÊNCIAS DA UNIVERSIDADE DE LISBOA

Departamento de Biologia Animal

ACULEATE HYMENOPTERANS COMMUNITIES AS A MANAGEMENT TOOL FOR THE EVALUATION OF HABITAT INTEGRITY AND QUALITY, IN THE VALE DO GUADIANA NATURAL PARK

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NOTA INTRODUTÓRIA

O conhecimento actual acerca da resposta das comunidades a diferentes habitats é limitado. Os Himenópteros Aculeados, especialmente Apiformes e Spheciformes, são um modelo privilegiado para responder a esta questão e posteriormente generalizar para outros grupos. Esta informação acerca das comunidades é muito importante para guiar acções de gestão em reservas naturais ou na minimização das actividades humanas.

Este estudo pretende analisar o uso de Himenópteros Aculeados como uma ferramenta de gestão para Áreas Protegidas ou para a regulação das actividades humanas. Foi conduzido em habitats com diferentes características do Parque Natural do Vale do Guadiana.

Este estudo será apresentado como um artigo científico de acordo com o regulamento dos estudos pós-graduados do Departamento de Biologia Animal.

RESUMO ALARGADO

A criação de Áreas Protegidas baseadas na manutenção de áreas naturais e na regulamentação das actividades humanas, foi uma das primeiras medidas tomadas para a protecção da biodiversidade. Todos os anos, conservacionistas e gestores de Áreas Protegidas gastam milhões para a conservação da biodiversidade e, apesar dos notórios esforços, a perda de biodiversidade prossegue a uma taxa alarmante. Considerando o investimento económico e social já realizado e em curso, seriam de esperar bons resultados. Contudo, a gestão de Áreas Protegidas é ainda frequentemente baseada em intuição e convicções pessoais em vez de num processo de decisão baseado em informação científica sólida. Apesar do investimento para a conservação estar a aumentar, a capacidade de medir o impacto destes investimentos para a conservação e documentar a efectividade das decisões de gestão não melhorou significativamente. O estabelecimento de sistemas para avaliar a eficácia da gestão é crucial para legitimar a importância destas áreas para a conservação e orientar os gestores para os seus objectivos.

A biodiversidade é usada frequentemente como indicadora de qualidade ambiental e integridade ecológica. No entanto, esta ferramenta tem uma capacidade de diferenciação entre habitats limitada e alguns estudos indicam até valores de biodiversidade mais elevados em habitats alterados.

É necessária uma compreensão mais aprofundada dos efeitos das alterações que contemple mudanças ao nível da estrutura, composição e função dos ecossistemas. É importante avaliar como as espécies usam a diversidade do seu habitat e diversidade paisagística.

Neste estudo propõe-se a utilização de Himenópteros Aculeados (um vasto grupo que inclui abelhas e vespas) como uma ferramenta para a avaliação da qualidade do habitat e respectiva integridade ecológica. Em Inglaterra já está a ser desenvolvido um sistema de classificação para avaliação da conservação baseado em comunidades de invertebrados e a sua relação com os habitats – o ISIS (Sistema de Informação Espécies de Invertebrados – Habitats).

As qualidades dos artrópodes terrestres como bioindicadores são geralmente reconhecidas. No entanto, o seu uso como ferramentas de monitorização é pouco

explorado. Os Aculeados (Himenóptera: Aculeata), especificamente, reúnem características excepcionais como bioindicadores. O sucesso da sua utilização como bioindicadores já foi provado por vários estudos, como por exemplo, Duelli&Obrist (1998), Duelli et al. (1999), Williams et al. (2001), Büchs (2003) e Hirsch&Wolters (2003). Além de reunirem características para uma amostragem fiável das populações em vários habitats como a sua distribuição alargada, elevada abundância, elevada riqueza específica, facilidade no método de captura, identificação e armazenamento, também têm qualidades importantes como bioindicadores: sensibilidade a alterações ambientais, fidelidade a tipos de habitat, ocupam vários nichos funcionais (predadores, polinizadores e cleptoparasitas), os seus padrões reflectem-se noutros taxa e uma elevada importância económica.

A importância económica tem sido cada vez mais notada visto que o alerta para uma crise na polinização foi lançado. Uma doença pandémica está a dizimar as populações da abelha do mel (*Apis mellifera*) e há agora a consciência do risco de se depender de apenas uma espécie para a polinização.

Para além dos polinizadores, com importância reconhecida, os Aculeados também incluem predadores, importantes para os ecossistemas naturais e agrícolas como agentes de controlo de pragas.

Os Aculeados respondem à necessidade de monitorização de habitats naturais e agrícolas baseando-se nos elementos mais valiosos e são dos poucos grupos que cumprem os três objectivos da bioindicação – protecção da natureza (espécies ameaçadas), protecção de plantas (polinização e controlo de pragas) e resiliência ecológica (padrões reflectem-se noutros taxa).

Com este estudo pretende-se (1) determinar as comunidades de Aculeados características de cada um dos habitats inicialmente definidos por cobertura vegetal e (2) diferenciar os habitats com base nas suas comunidades de Aculeados.

O trabalho foi realizado numa Área Protegida portuguesa – o Parque Natural do Vale do Guadiana. Este Parque Natural localiza-se no interior sul de Portugal, uma área extremamente quente e seca, associada com solos pobres. Mas, devido à presença do Rio Guadiana, tem também habitats mais húmidos (por ex. galerias ripícolas), reunindo uma grande diversidade de habitats.

A amostragem foi realizada de Março a Setembro de 2002, com recolha quinzenal de amostras referentes a um mês por cada estação do ano, com excepção do Inverno, em 8 habitats diferentes identificados pela cobertura vegetal dominante.

Utilizaram-se armadilhas Malaise para capturar os exemplares. Os Aculeados foram identificados ao nível da família e os Apiformes e os Spheciformes foram identificados ao nível do género.

A diferenciação dos habitats com base na análise das comunidades de Aculeados (famílias) foi menos notória do que com a análise das comunidades de Apiformes ou de Spheciformes (géneros).

O habitat mais humanizado, um campo agrícola em pousio (BCP), tal como esperado, exibiu uma menor diversidade de Aculeados, Apiformes e Spheciformes. Os habitats com maior humidade e maior mosaico paisagístico, uma floresta de Azinho orientada para a formação em Montado que ocorre naturalmente em Portugal (ALA) (Habitat 6310 da Directiva Habitats), uma galeria ripícola (RLR) e um bosque misto de Zimbros, ou Zimbral (COZ) (Habitat 9560 da Directiva Habitats), exibiram uma maior diversidade em geral, também de acordo com o esperado.

Os outros locais, tal como foi referido na caracterização da área em que o Parque Natural se localiza, são caracterizados por um baixo nível de humidade e solos pobres. Esses locais, um pinhal (CAP), um Montado de Sobro (PFM) (Habitat 6310 da Directiva Habitats), uma esteval (RLM) e uma plantação de eucaliptos (SDE), exibiram uma menor diversidade.

Foi possível a diferenciação de habitats com base na comunidade de Aculeados, Apiformes e Spheciformes. Os habitats foram organizados de forma diferente consoante os dados analisados, tal deve-se às diferentes variáveis que condicionam a distribuição dos grupos analisados. Na análise dos dados correspondentes aos Aculeados foi possível diferenciar os habitats de acordo com o grau de humidade, pelo que os habitats galeria ripícola (RLR) e bosque misto de Zimbro (COZ) foram diferenciados dos restantes. A diferenciação foi mais forte quando se analisaram os dados para os Apiformes e os Spheciformes. Com os dados dos Apiformes os habitats foram diferenciados de acordo com o grau de humidade e a diversidade de vegetação e com os dados dos Spheciformes os

habitats foram diferenciados principalmente de acordo com a exposição do solo, mas também de acordo com o grau de humidade.

Os habitats diferiram significativamente, em geral, numa ou mais famílias de Aculeados e num ou mais géneros de Apiformes e Spheciformes. A diferenciação dos habitats pelas famílias de Aculeados confirmou a escolha dos Apiformes e Spheciformes como grupos informativos visto que vários habitats diferiram na família Apidae (Apiformes) e na família Crabronidade (a maior família de Spheciformes).

A biologia dos vários géneros de Apiformes e Spheciformes e as características dos habitats foram analisadas para estabelecer o porquê da preferência de um habitat em relação a outro. O género *Apis* diferiu em muitos habitats analisados e de forma contrária aos outros géneros de Apiformes. A única espécie pertencente a este género que foi amostrada neste estudo foi a *A. mellifera* (abelha do mel), espécie que é mantida principalmente em populações "domésticas" para produção de mel e serviços de polinização, como tal a sua distribuição deverá ser mais condicionada pelas preferências dos apicultores do que pelas variáveis que iriam influenciar essa espécie em populações selvagens.

Para a família Sphecidae, e para os géneros *Melitturga* (Apiformes), *Dufourea* (Apiformes) e *Sphex* (Spheciformes) estabeleceu-se uma associação com um determinado habitat, BCP, RLM, RLR e BCP, respectivamente.

A notória preferência de várias famílias de Aculeados, e géneros de Apiformes e Spheciformes pela galeria ripícola (RLR) e pelo bosque misto de Zimbro (COZ) dá uma indicação geral das condições ideais para o desenvolvimento destes grupos e as características dos habitats pode ajudar na criação de refúgios adequados em campos agrícolas, por exemplo. Outros habitats naturais na área, como o pinhal (CAP), o Montado de Sobro (CAP) e o esteval (RLM) têm condições mais severas suportando uma diversidade menor e uma comunidade de Aculeados, Apiformes e Spheciformes muito diferente, mas igualmente importante.

Os Aculeados, especialmente Apiformes e Spheciformes, provaram ser uma ferramenta de gestão útil para avaliar a qualidade do habitat. Como desempenham papéis importantes em sistemas naturais e agrícolas neste estudo propõe-se a utilização de Apiformes e Spheciformes também em sistemas agrícolas. É reconhecida a necessidade de minimizar os impactos das actividades humanas, como a actividade agrícola. Alguns

autores chegam mesmo a considerar que os campos agrícolas são tão importantes como as Áreas Protegidas para a conservação, dado o efeito de complementaridade que pode ser gerado. A importância das áreas agrícolas é especialmente real na Europa visto que ao longo de vários séculos a maior parte do território foi alterado pela actividade humana – metade do território europeu é cultivado.

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Aculeate Hymenopterans communities as a management tool for the evaluation of habitat quality, in the Vale do Guadiana Natural Park

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ABSTRACT

The creation of Protected Areas was one of the first measures taken for the protection of biodiversity and it is still the most widely used. The establishment of systems to evaluate the effectiveness of the management of these areas is crucial to validate their importance in terms of conservation and guide the managers to their conservation goals. This can be efficiently done with the assessment of indicator groups like Aculeate Hymenopterans, the Aculeata. Aculeata, specifically Apiformes and Spheciformes, gather all the bioindication advantages of using arthropods and are essential to the sustainability of any natural or agricultural ecosystem since they include important pollinators and pest control agents. The Aculeata were sampled with Malaise traps in eight different habitats. The aim of the study was to determine the aculeate hymenopterans communities' characteristic of each of the habitat initially identified by habitat type (manly vegetation) and be able to differentiate the habitats based on their Aculeata communities. Specific richness, equitability and diversity were in general different among the eight habitats. The communities of each habitat were generally differentiated. Habitats differed in one or more families of Aculeata or genera of Apiformes and Spheciformes. It was even possible to associate family Sphecidae and genera *Melitturga*, *Dufourea* and *Sphex* with a specific habitat, BCP, RLM, RLR and BCP, respectively. Several families of Aculeata, genera of Apiformes and Spheciformes showed a preference for the riparian galery (RLR) and a Juniper mixed woodland (COZ), providing a general idea of the ideal conditions for the development of these groups. In conclusion, the results of this study supported the use of Aculeata, specifically Apiformes and Spheciformes, as a suitable management tool for natural areas, and probably also for agricultural areas too.

Key words: Aculeata, Apiformes, Spheciformes, bioindicators, management tool, natural area, agricultural area

RESUMO

A criação de Áreas Protegidas foi uma das primeiras medidas tomadas para a protecção da biodiversidade e é ainda uma das medidas mais usadas. O estabelecimento de sistemas para a avaliação da eficácia da gestão destas áreas é essencial para validação da importância destas áreas para a conservação e guiar gestores para os seus objectivos. Tal pode ser realizado eficazmente com a avaliação de grupos indicadores como os Aculeados. Os Aculeados, especialmente os Apiformes e os Spheciformes, reúnem todas as vantagens dos artrópodes como bioindicatores e são essenciais para a sustentabilidade de todos os ecossistemas, naturais e agrícolas, uma vez que incluem importantes polinizadores e agentes de controlo de pragas. Os Aculeados foram amostrados com armadilhas de Malaise em oito habitats diferentes. O objectivo deste estudo foi determinar as comunidades de Aculeados características de cada habitat inicialmente diferenciado com base na cobertura vegetal e diferenciar os habitats com base na sua comunidade de Aculeados. A riqueza específica, equitabilidade e diversidade foi, em geral, diferente entre os oito habitats. As comunidades de cada um dos habitat, em geral, foram diferenciadas. Os habitats exibiram diferenças em uma ou mais famílias de Aculeados e em um ou mais géneros de Apiformes e Spheciformes. Foi até possível associar a família Sphecidae e os géneros *Melitturga*, *Dufourea* e *Sphex* com um habitat específico, BCP, RLM, RLR e BCP, respectivamente. Várias famílias de Aculeados, e géneros de Apiformes e Spheciformes mostraram uma preferência pela galeria ripícola (RLR) e bosque misto de Zimbros (COZ) dando alguma ideia das condições ideais para o desenvolvimento destes grupos. Concluindo, os resultados deste estudo confirmam a utilidade de Aculeados, especialmente Apiformes e Sphecifrormes, como uma ferramenta de gestão adequada para áreas naturais, e provavelmente também para áreas agrícolas.

Palavras-chave: Aculeados, Apiformes, Spheciformes, bioindicadores, ferramenta de gestão, áreas naturais, áreas agrícolas.

INTRODUCTION

The awareness about a global environmental crisis is quite recent. The alert was given by the scientific community in the 1960s, but only by the 1970s politicians started to respond to this alert providing national legislation and international treaties concerning environmental conservation (Moomaw 2001; Franz 2003).

Creation of Protected Areas (PA) was one of the first measures taken for the protection of biodiversity and it is still the most widely used since the creation of the Yellowston Park in 1872. By 2002 there were 102.102 Protected Areas spread around the globe, making up to 12% of the terrestrial Earth surface (Moomaw 2001; Chape et al. 2003).

Conservationists and protected area managers spend millions of USDA each year to protect biodiversity and, despite this notorious effort, biodiversity loss continues at an alarming rate (Millennium Ecosystem Assessment 2005). Taking into account the large amount of financial support one should expect results but, unfortunately, management of Protected Areas is still frequently strongly biased by intuition and personal convictions instead of solid scientifically based decision-making process, and although the level of investment in conservation is growing, the ability to measure the conservation impact of these investments and documentation of the effectiveness of the management decisions is not (Parrish 2003). The establishment of systems to evaluate the effectiveness of management is crucial to validate the importance of these Areas in terms of conservation and guide the managers to their conservation goals (Mezquida et al. 2005).

Biodiversity is commonly used as an overall indicator for environmental quality. Yet, this tool has proven to have limited differentiation capacity (e.g. ranking natural and disturbed habitats) and some studies indicate that species diversity can be higher in disturbed habitats (Ottoneti et al. 2006, Tylianakis et al. 2005).

A more profound comprehension about the effects of the disturbance is needed and it is necessary to contemplate the changes at structure, composition and ecosystems function level (Tylianakis et al. 2004). It is important to evaluate how the species use the diversity of their habitat and evaluate landscape diversity. Landscape diversity can be evaluated through the identification of vegetation coverage, but this indicator may not detected rapid changes in ecosystem dynamics (Longcore 2003, Andersen et al. 2004).

In England, the ISIS (Invertebrate Species-Habitat Information System), a classification system for accessing conservation based on invertebrate communities and their relation with habitats, is already being developed (Webb&Lott 2006).

Like the ISIS, in this study we propose a methodology for evaluating habitat integrity and quality based in the analysis of a specific group of invertebrates, the Aculeate Hymenopterans (Arthropoda: Insecta), the Aculeata for short, a wide group that includes ants, bees and wasps.

The qualities of terrestrial arthropods as bioindicators are widely recognised, yet their use as assessment and evaluation tools is uncommon (Andersen et al. 2004).

In particular, the Aculeata gather exceptional characteristics as bioindicators. Their successful use as bioindicators has been noticed in several studies (Duelli&Obrist 1998, Duelli et al. 1999, Williams et al. 2001, Büchs 2003; Hirsch&Wolters 2003).
There are several characteristics considered important to the selection of bioindicators and the majority of them are an endowment of Aculeate hymenopterans, such as:

(1) Wide distribution, occupying a large variety of habitats (Büchs 2003, Gayubo et al. 2005);
(2) High abundance, allowing a significant representation in the samples and afterwards a simpler statistical treatment (McGeoch 1998, Duelli et al. 1999);
(3) High specific richness (Büchs 2003);
(4) Easily sampled and identified. The taxonomy is considerably stable and well known (McGeoch 1998, Andersen et al. 2004, Gayubo et al. 2005);
(5) Simple and reliable storage (McGeoch 1998; Niemi & MacDonalds 2004);
(6) Sensitivity to environmental disturbance. Their reduced size makes them efficient monitors of subtle but potentially important variations in their habitat (McGeoch 1998, Büchs 2003, Longcore 2003, Gayubo et al. 2005);
(7) Short generation times make them ideal to detect year-to-year changes (Longcore 2003);
(8) Fidelity to some areas or spatial units (Büchs 2003);
(9) Are part of several functional niches (predators, pollinators and cleptoparasites) essential to ecosystem functioning (McGeoch 1998);
(10) The patterns of biodiversity are reflected on other taxa, related or not (Gayubo et al. 2005);
(11) Economic importance, for pollination and pest control services (Gayubo et al. 2005).

Moreover, Aculeata are essential to the sustainability of any natural or agricultural ecosystem since they include important pollinators of wild and commercial plants (Tscharntke et al. 1998, Tylianakis et al. 2004).

Recently, pollinator conservation became a huge concern worldwide (Kevan 1999). This concern is probably related to the emergence of a pandemic disease that affects honey bees (*Apis mellifera*) dizimating the colonies to less than one third of the those existing 5 years before, and to the conscience of the risk of depending on a single species for pollination (UNEP 2000). Several alerts had been launched to the decline of native pollinators and the urgent need for their conservation (Buchmann & Nabhan 1996, Kearns et al. 1998, Cane & Tepedino 2001, Kevan & Phillips 2001, Steffan-Dewenter et al. 2005). Since one third of cultivated plants worldwide need pollination to produce fruits and seeds, it is clear that is necessary to protect native pollinators to guarantee agricultural production sustainability.

The International Initiative for the Conservation of Pollinators (IICP) was created as a consequence of the Convention for Biological Diversity leading to "The São Paulo Declaration on Pollinators" that is a report about the aspects to be considered in pollinators conservation and sustainable use in agricultural and natural habitats. One of the measures indicated was the assessment and monitorization of pollinators in natural and agricultural systems as a tool for leading land management to their conservation (Dias et al. 1999).

The Aculeata also include predators, important in the ecosystem as they control potential pest species. So, the evaluation of the Aculeata communities responds to the assessment needs both in natural and agricultural systems, under the IICP, focusing on the most valued elements (Kevan 1999).

According to Duelli & Obrist (2003), indicators can be grouped in three categories relating to their goals: a) *Nature protection* that corresponds to the diversity of threatened species and it is tested by the number of rare species; b) *Plant protection* that corresponds to the diversity of beneficial organisms tested by the abundance and species numbers and; c) *Ecological resilience* that corresponds to the diversity of all organisms tested by a set of selected taxa that represents the diversity of other organisms.

The Aculeata make one of the few groups that can meet all three indicator goals. Solitary bees are considered to be threatened species (*Nature Protection*), they include several beneficial organisms like pollinators, predators and parasitoids (*Plant*

Protection) and patterns of biodiversity are know to be reflected on other taxa (*Ecological resilience*).

Following the demand for insect bioindicators (McGeoch 2007), this study pretends to (1) assess the Aculeata communities' characteristic of each selected habitat type and (2) be able to differentiate the habitats based on their Aculeata communities.

MATERIAL AND METHODS

Study area

This study was performed in the Vale do Guadiana Natural Park (Fig. 1). It was established in 1995 and is one of the most recent Protected Areas in Portugal. It is located in the southeast part of Portugal, downstream of the Guadiana River (ICN 2000). It covers an area of 69773 ha and the altitude varies between 9 (minimum) and 370 (maximum) meters at the top of Alcaria and São Barão Hills (3).

As most of the south inland of Portugal, the area is extremely warm and dry, with temperatures that can reach 50ºC. Precipitation level normally doesn't reach the 400 mm (IM 2005, IM 2005). The region supports the lowest precipitation and the highest insolation and temperature levels of the country. (ICN 2000)

The termomediterranean climate and the poor soils are reflected in the habitat types, including the flora and fauna. The vast majority of the area is

Figure 1 – Sample locations in the Vale do Guadiana Natural Park (Portugal) according to UTM coordinates (10x10 Km). A single circle can enclose more than one locality.

ocupied by Holm Oak (*Quercus rotundifolia*), Gum Rockrose (*Cistus ladanifer*) and extensive cereal crop fields (Cardoso 2004). However, due to the close presence of Guadiana River other habitats can also be found, like riparian galleries and rocky slopes (ICN 2000)**.**

Field work

Samples were taken from 8 different habitats, whose characterizations concerning site name, altitude, UTM coordinates, dominant vegetation and Habitats Directive code (when applicable) are summarized in Table 1.

Code	**Site name**	**Altitude (m)**	**UTM (10×10)**	**Habitat**	**Habitats Directive Code (when applicable)**
ALA	Algor	180	29SPB07	Oak wood (*Quercus rotundifolia* with *Cistus ladanifer*)	9340
BCP	Braciais	170	29SPB26	Fallow land	n.a.
CAP	Cerro das Antenas	60	29SPB16	Pinewood (*Pinus pinea*)	n.a.
COZ	Corredoura	30	29SPB17	Mixed wood (*Quercus rotundifolia* and *Juniperus turbinata*)	5210
PFM	Mértola (montado)	70	29SPB16	Cork oak wood (*Quercus suber* with *Cistus ladanifer*)	9340
RLM	Limas (road)	100	29SPB28	Shrubland (*Cistus ladanifer*)	n.a.
RLR	Limas (river)	50	29SPB28	Riverside (mainly *Nerium oleander* with *Phragmytes australis*)	92D0
SDE	São Domingos	130	29SPB37	Eucalyptus plantation (*Eucalyptus globulus* with *Cistus ladanifer*)	n.a.

Table 1 – List of the 8 sites studied with their code name, site name, altitude (in meters), habitat type, considering plant coverage, and Directive Habitat Code (when applicable).

The sampling protocols took place in each habitat twice (15 days interval) in April (Spring), August (Summer) and October (Autumn) of 2003, performing 6 samples/habitat and a period of one month for each season (except Winter, when most insects are not active).

The sampling period extended from March to September 2003 using Malaise traps once is the most effective technique for the capture of flying insects for Hymenoptera and Diptera order (Bartlett 2000).

Laboratory work

The sampled specimens were sorted by orders using a binocular stereomicroscope Videq 80x. The Aculeata were identified to the family level using the taxonomic key of Goulet & Huber (1993). Ants (Formicidae) weren't accounted for once they have very different ecological requirements from the other Aculeata and the sampling technique applied is not the most indicated for assessment of ant diversity.

Within Aculeate Hymenopterans, only Spheciformes and Apiformes were identified to the genus level. These groups cover most of the characteristics for bioindication: are part of several functional niches (predators, cleptoparasites and pollinators), have economic importance (effectively accounted with pollinators) and have proven to be good bioindicators (Gayubo et al. 2005, Klein et al. 2002). The focus on these groups greatly reduces the identification effort also.

The apiformes were identified to the genus level using the taxonomic keys of Diniz, M. A. (1962) and the Spheciformes were identified according to Bitsch & Leclercq (1993), Bitsch et al. (1997) and Bitsch et al. (2001).

The specimens sorting to the species level requires a special preparation of the insect for identification which is lenghtfull and requires high level of expertise (drying, assembling and labelling) and it is necessary to consult a top senior specialist in Aculeata taxonomy which also considers time and money. Genus identification is far simpler. The insects can be preserved in 70% alcohol and the identification can be made without the need of a top senior taxonomist. Furthermore, some studies proved that identification of insects at genus level may give enough detailed information to permit the evaluation of the health or sustainability of the systems in question (Borges et al. 2002, Báldi 2003).

Data analysis

For the evaluation of Aculeata (families), Apiformes and Spheciformes (genera) diversity of different habitats at different year seasons, various indexes were used – specific richness (S), Shannon Weiner diversity index (H') and Pielou evenness index (E). Shannon Weiner diversity index was used as it is a simple quantitative expression that incorporates taxa richness, abundance and equitability (Elliot et al. 1999), is

moderately sensible to sample size, and it is better than all other diversity index's to discriminate samples (Ellison & van Ripper III 1998).

Differences between the specific richness (S), evenness (E) and diversity (H') for each site was calculated using the nonparametric test, Mann-Whitney U test ($p<0,05$).

In order to evaluate if the sampling effort was sufficient, accumulation curves were calculated for each site sampled.

Principal Components Analysis (PCA) was used as a preliminary tool to sort out the sites. The PCA can be used to classify variables detecting structure in the relationships between variables.

To evaluate the possible association between some families of Aculeata, Apiformes or Spheciformes genera and a specific site, a Correspondence Analysis was performed. Correspondence Analysis as any classification method enables a more user-friendly interpretation (Lee 1996).

A nonparametric Kruskal-Wallis One-Way ANOVA ($p<0,05$) was applied to determine differences among the Aculeata, Apiformes and Spheciformes communities at each site. Whenever differences among the sites were significant using Kruskal-Wallis, the Mann-Whitney U test was performed to find which sites differed (Zar 1999).

The analysis were performed using Diversity and Richness 3.0 (Seaby & Anderson, 2006), Statistica 7.0 Software (StatSoft, 2004) and R program (Vegan and MASS boockstores).

RESULTS

A total of 5716 Aculeata specimens were sampled, distributed by 14 families (Annex I, Table I-1). Within those specimens, 494 specimens were identified as Apiformes belonging to 25 genera, and 685 were identified as Spheciformes belonging to 25 genera also (Annex I, Table I-2 and I-3).

Diversity

Aculeate hymenopterans

The values of specific richness, equitability and diversity calculated for Aculeata at each sampling period for each site are summarized in the Annex II – Table II-1. The comparison between these values is summarized in Tables 2, 3 and 4.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,041126**	0,179654	0,699134	0,240260	0,484848	0,393939	0,588745
BCP	**0,041126**		0,132035	0,093074	0,393939	0,484848	**0,015152**	0,064935
CAP	0,179654	0,132035		0,309524	0,937229	0,937229	0,064935	0,309524
COZ	0,699134	0,093074	0,309524		0,179654	0,240260	0,818182	0,393939
PFM	0,240260	0,393939	0,937229	0,179654		1,000000	0,064935	0,484848
RLM	0,484848	0,484848	0,937229	0,240260	1,000000		0,179654	0,699134
RLR	0,393939	**0,015152**	0,064935	0,818182	0,064935	0,179654		0,179654
SDE	0,588745	0,064935	0,309524	0,393939	0,484848	0,699134	0,179654	

Table 2 – Values of Mann Whitney U test using the specific richness (S) of Aculeate hymenopterans (families) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		0,064935	0,937229	0,393939	0,818182	0,093074	0,309524	0,818182
BCP	0,064935		0,179654	0,393939	0,393939	0,937229	0,093074	0,240260
CAP	0,937229	0,179654		0,484848	0,818182	0,240260	0,393939	0,937229
COZ	0,393939	0,393939	0,484848		0,588745	0,309524	1,000000	0,818182
PFM	0,818182	0,393939	0,818182	0,588745		0,393939	0,937229	0,937229
RLM	0,093074	0,937229	0,240260	0,309524	0,393939		0,132035	0,393939
RLR	0,309524	0,093074	0,393939	1,000000	0,937229	0,132035		0,393939
SDE	0,818182	0,240260	0,937229	0,818182	0,937229	0,393939	0,393939	

Table 3 – Values of Mann Whitney U test using the evenness (E) of Aculeate hymenopterans (families) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		0,064935	0,937229	0,393939	0,818182	0,093074	0,309524	0,818182
BCP	0,064935		0,179654	0,393939	0,393939	0,937229	0,093074	0,240260
CAP	0,937229	0,179654		0,484848	0,699134	0,240260	0,393939	0,937229
COZ	0,393939	0,393939	0,484848		0,588745	0,309524	1,000000	0,818182
PFM	0,818182	0,393939	0,699134	0,588745		0,393939	0,937229	0,937229
RLM	0,093074	0,937229	0,240260	0,309524	0,393939		0,132035	0,393939
RLR	0,309524	0,093074	0,393939	1,000000	0,937229	0,132035		0,393939
SDE	0,818182	0,240260	0,937229	0,818182	0,937229	0,393939	0,393939	

Table 4 – Values of Mann Whitney U test using the diversity (H') of Aculeate hymenopterans (families) of each studied site. Significant values are in bold.

Equitability and diversity of Aculeata didn't show significant differences. The specific richness also didn't show significant differences. Only the site BCP shows significantly lower specific richness than sites ALA and RLR.

Concerning the Aculeata accumulation curves (Annex III – Fig. III-1), the sampling effort for the sites BCP, PFM, RLM and SDE seem to be sufficient once the number of families is constant since the third collection. The remaining sites need further sampling once the number of families did not reach asymptote along the three sampling periods.

Apiformes

The values of specific richness, equitability and diversity calculated for Apiformes at each sampling period for each site are summarized in the Annex II – Table II-1. The comparison between these values is summarized in Tables 5, 6 and 7.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,004329**	**0,025974**	**0,041126**	**0,041126**	**0,015152**	0,818182	0,064935
BCP	**0,004329**		**0,025974**	**0,002165**	0,064935	0,393939	**0,004329**	**0,025974**
CAP	**0,025974**	**0,025974**		**0,002165**	0,937229	0,309524	**0,025974**	0,937229
COZ	**0,041126**	**0,002165**	**0,002165**		**0,002165**	**0,002165**	0,179654	**0,004329**
PFM	**0,041126**	0,064935	0,937229	**0,002165**		0,393939	**0,041126**	0,937229
RLM	**0,015152**	0,393939	0,309524	**0,002165**	0,393939		**0,015152**	0,240260
RLR	0,818182	**0,004329**	**0,025974**	0,179654	**0,041126**	**0,015152**		**0,041126**
SDE	0,064935	**0,025974**	0,937229	**0,004329**	0,937229	0,240260	**0,041126**	

Table 5 – Values of Mann Whitney U test using the specific richness (S) of Apiformes (genera) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,004329**	**0,041126**	0,588745	**0,002165**	**0,008658**	0,818182	**0,025974**
BCP	**0,004329**		0,309524	**0,002165**	0,309524	0,699134	**0,008658**	0,393939
CAP	**0,041126**	0,309524		**0,004329**	0,699134	0,588745	0,064935	0,818182
COZ	0,588745	**0,002165**	**0,004329**		**0,002165**	**0,002165**	0,588745	**0,015152**
PFM	**0,002165**	0,309524	0,699134	**0,002165**		0,699134	**0,004329**	0,937229
RLM	**0,008658**	0,699134	0,588745	**0,002165**	0,699134		**0,015152**	0,699134
RLR	0,818182	**0,008658**	0,064935	0,588745	**0,004329**	**0,015152**		**0,025974**
SDE	**0,025974**	0,393939	0,818182	**0,015152**	0,937229	0,699134	**0,025974**	

Table 6 – Values of Mann Whitney U test using the evenness (E) of Apiformes (genera) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,004329**	**0,041126**	0,588745	**0,002165**	**0,008658**	0,818182	**0,025974**
BCP	**0,004329**		0,309524	**0,002165**	0,309524	0,699134	**0,008658**	0,393939
CAP	**0,041126**	0,309524		**0,004329**	0,699134	0,588745	0,064935	0,818182
COZ	0,588745	**0,002165**	**0,004329**		**0,002165**	**0,002165**	0,588745	**0,015152**
PFM	**0,002165**	0,309524	0,699134	**0,002165**		0,699134	**0,004329**	0,937229
RLM	**0,008658**	0,699134	0,588745	**0,002165**	0,699134		**0,015152**	0,699134
RLR	0,818182	**0,008658**	0,064935	0,588745	**0,004329**	**0,015152**		**0,025974**
SDE	**0,025974**	0,393939	0,818182	**0,015152**	0,937229	0,699134	**0,025974**	

Table 7 – Values of Mann Whitney U test using the diversity (H') of Apiformes (genera) of each studied site. Significant values are in bold.

The specific richness, equitability and diversity of Apiformes show significant differences among sites. The comparison of equitability and of diversity between sites shows the same results.

The equitability and diversity of sites BCP, PFM, RLM and SDE were significantly lower than sites ALA, COZ and RLR. Sites ALA and COZ also show a significantly higher equitability and diversity than site CAP.

The specific richness exhibited more differences among sites. Site BCP had a specific richness lower than ALA, CAP, COZ, RLR and SDE. Sites CAP, PFM and RLM show a specific richness significantly lower than ALA, COZ and RLR. Site ALA specific richness was significantly lower than COZ. And COZ and RLR specific richness was significantly higher than SDE.

The accumulation curves for the Apiformes genera (Annex III – Fig. III-2), show that only sites BCP and RLM were sufficiently sampled, the number of taxa remains constant since the third collection. The remaining sites need further sampling.

Spheciformes

The values of specific richness, equitability and diversity calculated for Spheciformes at each sampling period for each site are summarized in the Annex II – Table II-1. The comparison between these values is summarized in Tables 8, 9 and 10.

	ALA	**BCP**	**CAP**	**COZ**	**PFM**	**RLM**	**RLR**	**SDE**
ALA		0,064935	0,179654	**0,041126**	0,699134	0,240260	0,132035	0,093074
BCP	0,064935		0,179654	**0,008658**	0,093074	0,393939	**0,015152**	0,393939
CAP	0,179654	0,179654		**0,015152**	0,309524	0,699134	**0,025974**	0,588745
COZ	0,041126	**0,008658**	**0,015152**		0,132035	**0,015152**	0,309524	**0,004329**
PFM	0,699134	0,093074	0,309524	0,132035		0,240260	0,393939	0,132035
RLM	0,240260	0,393939	0,699134	**0,015152**	0,240260		**0,041126**	1,000000
RLR	0,132035	**0,015152**	**0,025974**	0,309524	0,393939	**0,041126**		**0,008658**
SDE	0,093074	0,393939	0,588745	**0,004329**	0,132035	1,000000	**0,008658**	

Table 8 – Values of Mann Whitney U test using the specific richness (S) of Spheciformes (genera) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,041126**	0,179654	**0,041126**	0,937229	0,240260	0,484848	0,093074
BCP	**0,041126**		0,484848	**0,002165**	**0,041126**	0,588745	**0,008658**	0,818182
CAP	0,179654	0,484848		**0,008658**	0,179654	1,000000	0,064935	0,699134
COZ	**0,041126**	**0,002165**	**0,008658**		0,064935	**0,015152**	0,064935	**0,002165**
PFM	0,937229	**0,041126**	0,179654	0,064935		0,179654	0,818182	0,064935
RLM	0,240260	0,588745	1,000000	**0,015152**	0,179654		**0,041126**	0,818182
RLR	0,484848	**0,008658**	0,064935	0,064935	0,818182	**0,041126**		**0,008658**
SDE	0,093074	0,818182	0,699134	**0,002165**	0,064935	0,818182	**0,008658**	

Table 9 –Values of Mann Whitney U test using the evenness (E) of Spheciformes (genera) of each studied site. Significant values are in bold.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		**0,041126**	0,179654	**0,041126**	0,937229	0,240260	0,484848	0,093074
BCP	**0,041126**		0,484848	**0,002165**	**0,041126**	0,588745	**0,008658**	0,818182
CAP	0,179654	0,484848		**0,008658**	0,179654	1,000000	0,064935	0,699134
COZ	**0,041126**	**0,002165**	**0,008658**		0,064935	**0,015152**	0,064935	**0,002165**
PFM	0,937229	**0,041126**	0,179654	0,064935		0,179654	0,818182	0,064935
RLM	0,240260	0,588745	1,000000	**0,015152**	0,179654		**0,041126**	0,818182
RLR	0,484848	**0,008658**	0,064935	0,064935	0,818182	**0,041126**		**0,008658**
SDE	0,093074	0,818182	0,699134	**0,002165**	0,064935	0,818182	**0,008658**	

Table 10 – Values of Mann Whitney U test using the diversity (H') of Spheciformes (genera) of each studied site. Significant values are in bold.

In what concerns the Spheciformes genera, the specific richness, equitability and diversity show significant differences among sites, although less than with the Apiformes data. Again the results for differences in equitability and diversity between sites were the same.

Site COZ equitability and diversity was significantly higher than sites ALA, BCP, CAP, RLM and SDE. BCP shows a significantly lower equitability and diversity than ALA, PFM and RLR, and RLR equitability and diversity was significantly higher than RLM and SDE.

Specific richness of site COZ was significantly higher than ALA, BCP, CAP, RLM and SDE. Finally, site RLR shows a significantly higher specific richness than BCP, CAP, RLR and SDE.

As for the Spheciformes accumulation curves (Annex III – Fig. III-3), sites BCP, CAP and RLM seem to show a sufficient sampling. The remaining sites, as in the previous analysis of Aculeata and Apiformes, need further sampling.

Aculeate hymenopterans

The Principal Components Analysis performed on the Aculeata data (Figure 2) shows the separation between sites RLR and COZ and the remaining sites, mainly along the first axis. In fact, the first axis explained 77,5% of the variability while the second explained 12,5%. Together, they explained for 90% of the initial variability.

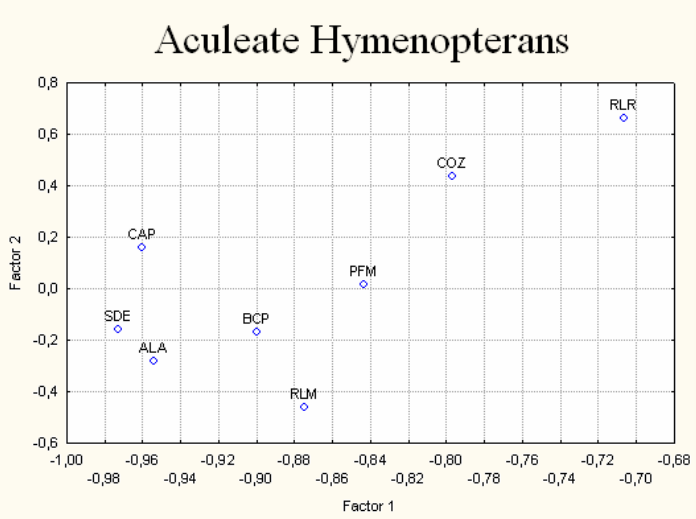

Figure 2 - Results of the PCA applied to the distribution of the several Aculeate Hymenoptera families with respect to the studied sites at Vale do Guadiana Natural Park.

Through the correspondence analysis related to Aculeata data (Fig. 3), no association was found between the sites and the Aculeata families. This is visible except for the possible association between the site BCP and the Sphecidae family.

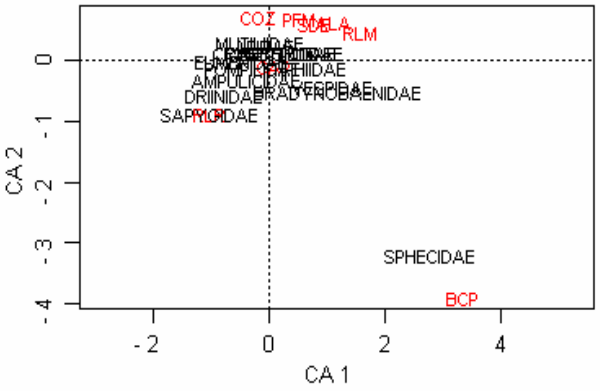

Figure 3 - Results of the Correspondence Analysis applied to the distribution of the several Aculeata families with respect to the studied sites at Vale do Guadiana Natural Park.

Taking into account the Krusskal-Wallis One-Way ANOVA the studied sites differed in their Aculeata communities (Annex IV – Table IV-1), namely in relation to the families Apidae (p=0,0002), Crabronidae (p=0,007), Eumenidae (p=0,0035) and Pompilidae (p=0,0009).

On the other hand, the Mann-Whitney U test with the Aculeata data (Table 11) indicates that some habitats didn't differ. Site pairs ALA/CAP, PFM and SDE, CAP/PFM, RLM and SDE, PFM/RLM and SDE, RLM/BCP and COZ, and COZ/RLR didn't show significant differences among them.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		Apidae p=0,002165	-	Apidae p=0,002165 Mutiliidae p=0,015152	-	Apidae p=0,041126	Crabronidae p=0,008658 Pompilidae p=0,004329	-
BCP	Apidae p=0,002165		Apidae p=0,004329	Apidae p=0,002165 Crabronidae p=0,008658 Pompilidae p=0,004329 Apidae p=0,025974	Apidae p=0,025974	-	Apidae p=0,002165 Crabronidae p=0,004329 Pompilidae p=0,004329	Apidae p=0,002165
CAP	-	Apidae p=0,004329		Apidae p=0,002165 Crabronidae p=0,025974 Pompilidae p=0,008658	-	-	Apidae p=0,025974 Crabronidae p=0,008658 Mutiliidae p=0,041126 Pompilidae p=0,004329 Tiphiidae p=0,041126	-
COZ	Apidae p=0,002165 Mutiliidae p=0,015152	Apidae p=0,002165 Crabronidae p=0,008658 Pompilidae p=0,004329	Apidae p=0,002165 Crabronidae p=0,025974 Pompilidae p=0,008658		Pompilidae p=0,025974	Apidae p=0,002165 Pompilidae p=0,004329	-	Apidae p=0,004329 Pompilidae p=0,025974
PFM	-	Apidae p=0,025974	-	Pompilidae p=0,025974		-	Mutiliidae p=0,041126 Pompilidae p=0,008658 Tiphiidae p=0,004329	-
RLM	Apidae p=0,041126	-	-	Apidae p=0,002165 Pompilidae p=0,004329	-		Apidae p=0,004329 Crabronidae p=0,004329 Pompilidae p=0,002165	Apidae p=0,041126
RLR	Crabronidae p=0,008658 Pompilidae p=0,004329	Apidae p=0,002165 Crabronidae p=0,004329 Pompilidae p=0,004329	Apidae p=0,025974 Crabronidae p=0,008658 Mutiliidae p=0,041126 Pompilidae p=0,004329 Tiphiidae p=0,041126	-	Mutiliidae p=0,041126 Pompilidae p=0,008658 Tiphiidae p=0,004329	Apidae p=0,004329 Crabronidae p=0,004329 Pompilidae p=0,002165		Crabronidae p=0,004329 Pompilidae p=0,008658
SDE	-	Apidae p=0,002165	-	Apidae p=0,004329 Pompilidae p=0,025974	-	Apidae p=0,041126	Crabronidae p=0,004329 Pompilidae p=0,008658	

Table 11 – Mann Whitney U test values: comparison between the Aculeated hymenopterans families of each studied site with indication of the families significantly different ($p<0,05$).

The remaining pairs of sites show differences in the community of one or several Aculeata families.

Several pairs of sites exhibited differences relating solely to the family Apidae – ALA/BCP, ALA/COZ, ALA/RLM, BCP/CAP, BCP/PFM, BCP/SDE and RLR/SDE.

Others site pairs also differed in only one family. Site pairs ALA/COZ differed in the Mutillidae family and COZ/PFM differed in the Pompilidae family.

The others site pairs differed in a combination of families. Site pairs BCP/COZ, BCP/RLR, CAP/COZ and RLM/RLR were significantly different in relation to Apidae, Crabronidae and Pompilidae families, RLR/ALA and RLR/SDE differed in Crabronidae and Pompilidae families, COZ/RLM and COZ/SDE differed in Apidae and Pompilidae families, PFM/RLR differed in Mutillidae, Pompilidae and Tiphiidae families, and CAP/RLR differed in Apidae, Crabronidae, Mutillidae, Pompilidae and Tiphiidae families.

Apiformes

The Principal Components Analysis performed on the Apiformes data (Fig. 4) shows a more clear separation, than with the Aculeata data, among the studied sites or habitats, distributed along both axes. Both axes explain for 58,2% of the initial variability, 38,1% and 20,1% by axes 1 and 2, respectively. Sites CAP, PFM and SDE form a clear group at the base of both 1 and 2 axes while COZ, RLM and RLR seem to form a group at the maximum of both 1 and 2 axes.

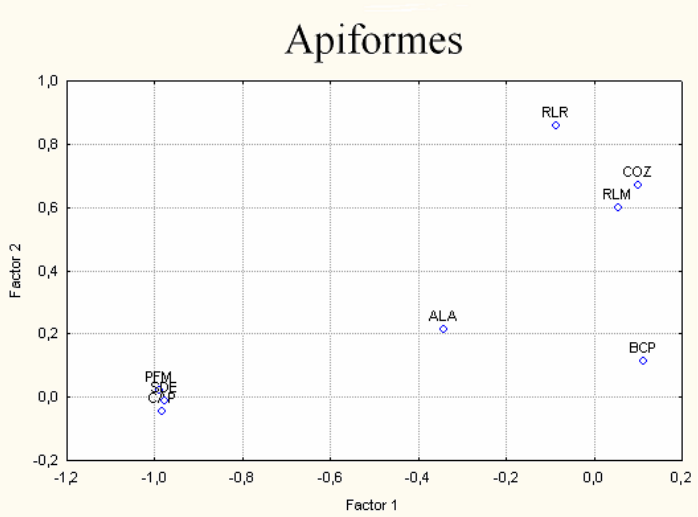

Figure 4 - Results of the PCA applied to the distribution of the several Apiformes genera with respect to the studied sites at Vale do Guadiana Natural Park.

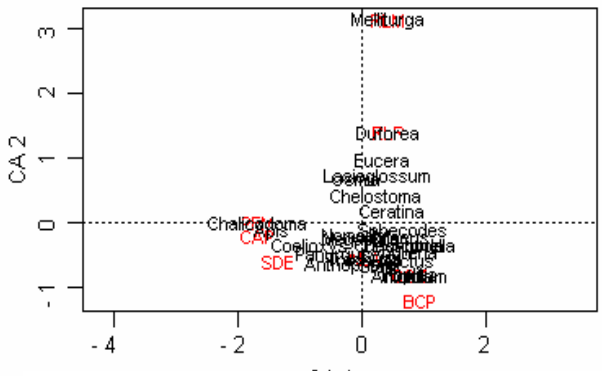

Figure 5 - Results of the Correspondence Analysis applied to the distribution of the several Apiformes genera with respect to the studied sites at Vale do Guadiana Natural Park.

The remaining sites, ALA and BCP are segregated from the previous groups.

Through the correspondence analysis performed on Apiformes data (Fig. 5), the association between habitats and genera seems more perceptible than on the Aculeata analysis, namely in the association between genus *Melliturga* and the site RLM and genus *Duforea* and the site RLR. As for the other sites, they are more spread along the chart than on the Aculeata analysis, and some genera seem to be closer to a specific site.

Taking into account the Krusskal-Wallis One-Way ANOVA the studied sites differed in their Apiformes communities (Annex IV – Table IV-2) namely in *Apis* (p=0,0001), *Ceratina* (p=0,0002), *Halictus* (p=0,0073), *Lasioglossum* (p= 0) and *Sphecodes* (p=0,0433) genera.

On the other hand, the Mann-Whitney U test analysis of the Apiformes data (Table 12) indicates that some pairs of sites also didn't differ. Site pairs ALA/BCP, ALA/CAP, ALA/PFM, ALA/RLM, BCP/RLM, CAP/PFM, CAP/SDE, COZ/RLR and PFM/SDE didn't show significant differences among them.

The remaining pairs of sites show differences in the community of one or several Apiformes genera.

Several pairs of sites exhibited differences relating solely to the genus *Apis* – ALA/COZ, ALA/SDE, BCP/CAP, BCP/PFM, BCP/SDE, RLM/CAP, RLM/PFM and RLM/SDE.

Other site pairs also differed in only one genus. Site pairs RLR/ALA, RLR/BCP and RLR/CAP differed in the genus *Lasioglossum* and RLR/PFM and RLR/RLM differed in the genus *Hylaeus*.

The other site pairs differed in a combination of genera. Site pairs COZ/RLM and RLR/SDE were significantly different relating to genera *Apis* and *Lasioglossum*, COZ/PFM differed in genera *Apis* and *Ceratina*, BCP/COZ differed in genera *Ceratina* and *Lasioglossum*, CAP/COZ differed in genera *Apis*, *Ceratina* and *Hylaeus*, and COZ/SDE differed in genera *Apis*, *Ceratina* and *Lasioglossum*.

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		-	-	*Apis* p=0,025974	-	-	*Lasioglossum* p=0,008658	*Apis* p=0,002165
BCP	-		*Apis* p=0,015152	*Ceratina* p=0,002165 *Lasioglossum* p=0,015152	*Apis* p=0,015152	-	*Ceratina* p=0,002165	*Apis* p=0,002165
CAP	-	*Apis* p=0,015152		*Apis* p=0,025974 *Ceratina* p=0,002165 *Hylaeus* p=0,015152	-	*Apis* p=0,015152	*Lasioglossum* p=0,015152	-
COZ	*Apis* p=0,025974	*Ceratina* p=0,002165 *Lasioglossum* p=0,015152	*Apis* p=0,025974 *Ceratina* p=0,002165 *Hylaeus* p=0,015152		*Apis* p=0,025974 *Ceratina* p=0,008658	*Apis* p=0,002165 *Lasioglossum* p=0,015152	-	*Apis* p=0,002165 *Ceratina* p=0,002165 *Lasioglossum* p=0,015152
PFM	-	*Apis* p=0,015152	-	*Apis* p=0,025974 *Ceratina* p=0,008658		*Apis* p=0,015152	*Hylaeus* p=0,041126	-
RLM	-	-	*Apis* p=0,015152	*Apis* p=0,002165 *Lasioglossum* p=0,015152	*Apis* p=0,015152		*Hylaeus* p=0,002165	*Apis* p=0,002165
RLR	*Lasioglossum* p=0,008658	*Ceratina* p=0,002165	*Lasioglossum* p=0,015152	-	*Hylaeus* p=0,041126	*Hylaeus* p=0,002165		*Apis* p=0,004329 *Lasioglossum* p=0,002165
SDE	*Apis* p=0,002165	*Apis* p=0,002165	-	*Apis* p=0,002165 *Ceratina* p=0,002165 *Lasioglossum* p=0,015152	-	*Apis* p=0,002165	*Apis* p=0,004329 *Lasioglossum* p=0,002165	

Table 12 - Mann Whitney U test values: comparison between the Apiformes genera of each studied site with indication of the families significantly different (p<0,05).

Spheciformes

Concerning the Principal Components Analysis performed on the Spheciformes data (Fig. 6) the separation between the studied habitats it is also more visible than with the Aculeata data. But, as with the Aculeata data, axis 1 is the more explanatory axis. Both factors explain for 64,3% of the initial variability, 49,4% and 14,9% by axes 1 and 2, respectively. Site BCP clearly differentiates from all the others. And sites ALA, CAP, PFM, RLM and SDE seem to form a group while COZ and RLR forms another one.

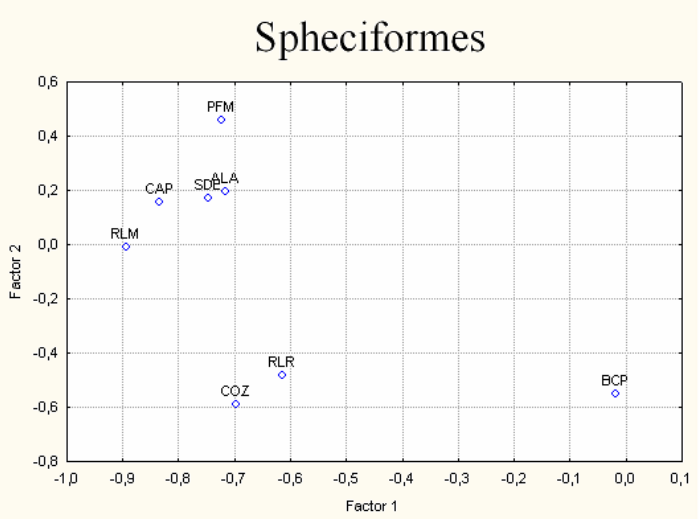

Figure 6 - Results of the PCA applied to the distribution of the several Spheciformes genera with respect to the studied sites at Vale do Guadiana Natural Park.

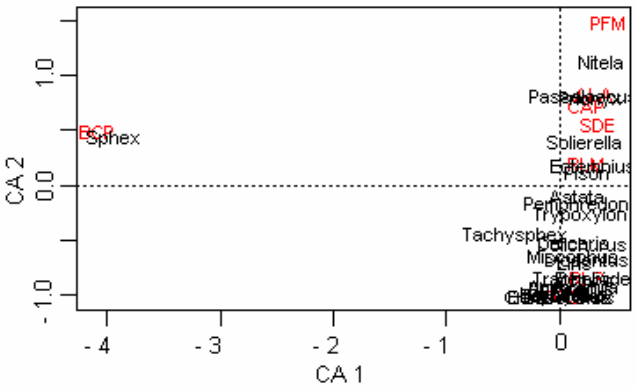

Figure 7 - Results of the Correspondence Analysis applied to the distribution of the several Spheciformes genera with respect to the studied sites at Vale do Guadiana Natural Park.

The correspondence analysis related to Spheciformes (Fig. 7) shows that there is a clear association between genus *Sphex* and site BCP. The other sites are also more spread than on the Aculeata analysis and some genera seem to be closer to a specific site.

Taking into account the Krusskal-Wallis One-Way ANOVA the studied sites differed in their Spheciformes communities (Annex IV – Table IV-3) – *Diodontus* (p=0,0009), *Dryudella* (p=0,0026), *Harpactus* (p= 0,0008), *Miscophus* (p=0,0101), *Nitela* (p=0,0150), *Tachytes* (p=0,0026) and *Trypoxylon* (p=0,0004).

On the other hand, as in the Mann-Whitney U test analysis of Aculeata and Apiformes data, in the analysis of the Spheciformes data (Table 13), some pairs of sites also didn't differ. Site pairs ALA/PFM, BCP/CAP and SDE, CAP/PFM and SDE,

	ALA	BCP	CAP	COZ	PFM	RLM	RLR	SDE
ALA		*Passaloecus* p=0,025974	*Passaloecus* p=0,041126	*Nitela* p=0,025974	-	*Passaloecus* p=0,041126	*Miscophus* p=0,015152 *Passaloecus* p=0,041126 *Trypoxylon* p=0,004329	*Passaloecus* p=0,041126
BCP	*Passaloecus* p=0,025974		-	*Trypoxylon* p=0,008658	*Nitela* p=0,015152	-	*Miscophus* p=0,025974 *Trypoxylon* p=0,002165	-
CAP	*Passaloecus* p=0,041126	-		*Trypoxylon* p=0,025974	*Trypoxylon* p=0,041126	-	*Miscophus* p=0,025974 *Trypoxylon* p=0,002165	-
COZ	*Nitela* p=0,025974	*Trypoxylon* p=0,008658	*Trypoxylon* p=0,025974		-	*Trypoxylon* p=0,025974	*Trypoxylon* p=0,008658	-
PFM	-	*Nitela* p=0,015152	*Trypoxylon* p=0,041126	-		-	*Nitela* p=0,041126 *Trypoxylon* p=0,015152	-
RLM	*Passaloecus* p=0,041126	-	-	*Trypoxylon* p=0,025974	-		-	-
RLR	*Miscophus* p=0,015152 *Passaloecus* p=0,041126 *Trypoxylon* p=0,004329	*Miscophus* p=0,025974 *Trypoxylon* p=0,002165	*Miscophus* p=0,025974 *Trypoxylon* p=0,002165	*Trypoxylon* p=0,008658	*Nitela* p=0,041126 *Trypoxylon* p=0,015152	-		*Miscophus* p=0,025974 *Trypoxylon* p=0,002165
SDE	*Passaloecus* p=0,041126	-	-	-	-	-	*Miscophus* p=0,025974 *Trypoxylon* p=0,002165	

Table 13 - Mann Whitney U test values: comparison between the Spheciformes genera of each studied site with indication of the families significantly different (p<0,05).

COZ/SDE, PFM/RLM and RLM/RLR and SDE didn't show significant differences among them.

The remaining pairs of sites show differences in the community of one or several Spheciformes genera.

Some pairs of sites exhibited differences relating solely to the genus *Trypoxylon* – COZ/BCP, COZ/CAP, COZ/RLM, COZ/RLR and CAP/PFM.

Other site pairs differed in only one genus. Site pairs ALA/BCP, ALA/CAP, ALA/COZ, ALA/RLM and ALA/SDE differed in the genus *Passaloecus*, and PFM/BCP and PFM/SDE differed in the genus *Nitela*.

The other site pairs differed in a combination of genera. Site pairs RLR/BCP, RLR/CAP and RLR/SDE were significantly different relating to genera *Miscophus* and *Trypoxylon*, PFM/RLR differed in genera *Nitela* and *Trypoxylon*, and ALA/RLR differed in genera *Miscophus*, *Passaloecus* and *Trypoxylon*.

DISCUSSION

Diversity

The several analyses of the specific richness, equitability and diversity performed for Aculeata at the family level didn't enable the differentiation between habitats. The family taxonomic level seems to be too high to establish community differentiation between habitats. Yet, the Apiformes and Spheciformes analysis allowed the segregation of the habitats. The study with these groups was carried out at the genera level and, as happened with other arthropods (Andersen 1995, Borges et al. 2002, Cardoso et al. 2004), is still informative.

Habitats ALA, COZ and RLR stood out as the more diverse and BCP as the less diverse. Site BCP represents the type of habitat that experiences the greatest human intervention as it is an agricultural fallow land. As so, it is expected to show a lower specific richness, equitability and diversity (Adeduntan et. al 2007).

The sites ALA, COZ and RLR are habitats less altered. ALA is an Holm Oak Montado woodland, being the Holm Oak native in Portugal, classified under the code 9340 in the Habitats Directive (ETC/NC 1999), COZ is a mixed *Juniperus* woodland, a habitat type, protected by the Habitats Directive (code 5210), that occurs naturally in this area of Portugal (ETC/NC 1999) and RLR is a riparian gallery, classified under the

code 92D0 in the Habitats Directive, and by its natural characteristics is one of the most dynamic habitats playing usually a crucial role in biological diversity (Brunnel & Dupuis 1993, Naiman et al. 1993). All three are expected to show a reasonably high specific richness, equitability and diversity, especially site RLR.

The sampling effort was insufficient in the generality of the sites. However, the sampling effort seemed sufficient in more sites when the analysis was performed with Aculeata. This is justified by the higher taxonomic level used (family). It is easier to sample one individual from a larger group (family) than from a smaller group (genus).

The sites for which the sampling effort was sufficient were those that proved to be the less diverse. For instance, BCP, a fallow land, was the less diverse for all sets of data (Aculeata, Apiformes and Spheciformes) and show adequate sampling for all data. On the other hand, the more diverse sites, ALA, COZ and RLR, show insufficient sampling for all sets of data.

Communities and habitat evaluation

The PCA with all groups studied allow the differentiation between 2 or more groups of habitats. The different groups studied respond to different biotic and abiotic characteristics. As the habitats studied provide different biotic and abiotic characteristics, they can be differentiated according to the communities of Aculeata, Apiformes and Spheciformes.

Aculeata communities seem to be conditioned mainly by the habitat moisture level. The sites with the highest moisture level, site RLR (riparian gallery) and COZ (mixed *Juniperus* woodland), were segregated from the others.

On the other hand, apiformes communities are conditioned by vegetation diversity as well as the moisture level. The habitats with lower moisture level and consequently vegetation diversity, PFM, CAP and SDE, were segregated from the others. PFM is a Cork oak Montado, a shrubland with disperse cork oak trees, SDE is an Eucalyptus plantation, a very water demanding stand (Florence 1996), and CAP is a pine tree plantation with very dry soil. On the other side of the moisture level, we found the habitats with higher moisture and vegetation diversity, COZ, RLM and RLR, which were also segregated from the others. All are forests with more open canopies which allows greater groundcover vegetation diversity. This type of distribution pattern is

shared with most adult diurnal Lepidopterans who are also pollinators (Kitahara et al. 2007).

Spheciformes communities are also conditioned by moisture but other factor seems to be the more determinant, like the soil exposure (Gayubo et al. 2000). The great importance of soil exposure may relate to Spheciformes nesting requirements. The habitat with greater soil exposure, site BCP, an open fallow land, was segregated from the others. As previously, the habitats COZ and RLR are segregated from the others. Their abiotic characteristics (e.g. more moisture) and the associated Spheciformes genera can explain this separation.

The CA of all groups allowed some degree of association between habitats and some family or genus. This can validate the quality of these groups as bioindicators as it confirms the fidelity of some members of these groups to a spatial unit (Büchs 2003).

As previously referred to diversity, the family level seems too broad to allow strong differentiation. Families include several genera and species that may include different ecological preferences. Only the family Sphecidae seems to show a strong preference for site BCP. This group is a cosmopolitan family of mud-dauber and thread-waisted wasps. They are essentially predators of Araneae, Orthopteroids or Lepidoptera larvae. Most subfamilies of this group are thread-waisted wasps nesting in pre-existing cavities or, more often, construct a nest in the ground. Soil type and prey abundance is very important for the settlement of this family (Goulet & Huber 1993, Gayubo et al. 2000). Agricultural fields have a less compacted soil that may be more adequate for the construction of nests of some Sphecidae subfamilies and may show great abundances of some pest species of Orthopteroids and Lepidoptera (Adeduntan et. al 2007) and generalist predators like Araneae (Jago 1998, Borror & DeLong 1988). The predation on pest species makes Sphecidae potentially useful as biological control agents for crop production (Frank et al. 1995), with economic importance for pest control services, of the desirable itens for bioindicator selection (Gayubo et al. 2005). The distribution of this family is greatly conditioned by the abundance of their preys. This kind of distributional pattern also happens with insectivorous birds who share the same ecological niche (Sipura 1999). This factor (abundance of preys in agricultural fields) is also correlated with the diversity of other groups of predator insects such as ground-beetles (e.g. Silva et al 2008).

Both Apiformes and Spheciformes provide a higher level of association among habitats and some genera. Even though only the Apiformes genera *Melitturga* and

Dufourea and the Spheciformes genus *Sphex* showed a clear association with a specific habitat, in both analyses the sites are quite differentiated and there seems to be an indication of the preference of some Apiformes and Spheciformes genera for a specific site. There is a predictable greater proximity of ecological preferences among species of the same genus than among species of the same family that allows a greater segregation of habitats at genera level.

The genus *Melitturga* shows an association with site RLM. Species belonging to the genus *Melitturga* generally make their nests in nearly horizontal and mostly barren ground. They provide their nests with a pollen mass (Rozen 1965). This habitat, as a shrubland, provides some patches of horizontal, barren ground for nesting and probably also plants that serve as food sources for the species of *Melitturga* present.

As for the genus *Dufourea*, it reveals an association with site RLR, this genus nests in relatively moist soil, cells have a rather weak lining and a retardant to water at least on the floor. They provide each cell with a sphere of pollen, mealy-moist and without waterproof coating (Rozen & McGinley 1976). Site RLR is a riparian gallery, as referred before, is the most humid. Taking into account this abiotic factor and the genus *Dufourea* needs for moisture, RLR is an adequate habitat for this genus.

The genus *Sphex* showed an association with collection site BCP. This genus belongs to the Sphecidae family and, as so, the association between BCP and the Sphecidae it is actually the association between a genus belonging to the Sphecidae family (*Sphex*) and BCP, not an association with the family as a whole. Members of the genus *Sphex* dig their nests on soils with gravel and provision them with their preys – young Acridiidae and Locustidae (Ashmead 1894). Locusts are well known agricultural field pests (Jing & Kang 2003), so they must exist in great numbers in BCP site, justifying the preference of the genus *Sphex* for this habitat.

Taking into account the Kruskal-Wallis One-Way ANOVA the habitats differ in several families of Aculeata (Annex IV – Table IV-1) and genera of Apiformes (Annex IV – Table IV-2) and of Spheciformes (Annex IV – Table IV-3).

Regarding the Aculeata, the habitats show significant differences in the families Apidae, Crabronidae, Eumenidae and Pompilidae.

The significance of the apiformes (family Apidae) confirms the usefulness of this group as informative of habitat conditions, showing distinct preferences. Apidae are pollinators with several nesting behaviours and social organization, so their distribution is manly conditioned by food resources (they may be polylectic, oligoletic or

specialists) and nesting requirements (they can be miners, carpenters, masons, leafcutters and social nesters), variable according to the genera considered (Patenaude 2007).

Family Crabronidae is the most speciose of the Spheciformes families also confirming the usefulness of this group as a whole to give information on habitat requirements. Members of this family are predators of a wide range of insects and spiders. They show a wide range of nesting behaviours – they can excavate theirs nest (burrowers), nest in pre-existing cavities or constructed tubular mud nests. Their distribution is also conditioned by food resources (prey abundance) and nesting conditions (usually soil type), variable according to the genera considered (Goulet & Huber 1993).

The species of family Eumenidae are predators of Lepidoptera and also show several nesting behaviours – they can excavate their nest in the soil or plant stems. Their distribution is also conditioned by food resources (prey abundance) and nesting conditions, variable according to the genera considered (Evans 1977).

Members of family Pompilidae are predators of Araneae, solitary and show a relatively consistent nesting behaviour – their larva develops on paralyzed spider in a cell excavated by the female or in a pre-existing cavity. Their distribution is also conditioned by Araneae abundance and nesting conditions (usually, soil type) (Goulet & Huber 1993).

As for Apiformes, the habitats differ in *Apis*, *Ceratina*, *Halictus*, *Lasioglossum* and *Sphecodes* genera. These set of genera have very distinctive habitat preferences relating to their functional niches (pollinators and cleptoparasites) and nesting preferences. This diversity in functional niches is an important bioindication characteristic (McGeoch 1998).

Within genus *Apis* only one species was sampled in this study, the *Apis mellifera* (honey bee). The populations of this species are mainly managed by humans. It nests in structures built for honey production and are managed for crop pollination. The honey bee can also survive in the wild, nesting in hollow trees and other shelters (Brewer 1995). The distribution of this species is mainly influenced by human preferences, habitats are picked by beekeepers for the type and abundance of floral resources. The wild populations are influenced by availability of shelters for the colonies and the abundance of floral resources as they pollinate on a wide variety of flowering plants.

The information provided by this genus must be carefully analyzed as it may not reflect the natural preferences of the genus but the preferences of the beekeepers.

Members of genus *Ceratina* are pollinators that usually nest in plant stems like brambles and rush. So they depend on floral resources, as all pollinators, and on the existence of suitable plants for nesting (Terzo & Ortiz-Sánchez 2004).

The species of genus *Halictus* (sweat bees) are pollinators that usually excavate their nests in the soil and exhibit a great variety of social behaviour – sweat bees include solitary, communal, semisocial and primitively eusocial species. Their distribution depends on the existence of suitable nesting sites and floral resources (Richards 2001).

Genus *Lasioglossum* is closely related to genus *Halictus*, their members are also known as sweat bees. Like *Halictus*, *Lasioglossum* species are also pollinators that usually excavate their nests in the soil and exhibit a great variety of social behaviour. Their distribution depends on suitable nesting sites and floral resources (Gregory & Wright 2005).

The species of genus *Sphecodes* are cleoptoparasites on other genera of bees, primarily on genera within the family Halictidae (*Halictus*, *Lasioglossum* and *Nomia*), being commonly known as "cuckoo bees". Their distribution depends on the presence of nests of Halictidae (Engel 2006).

Finally, regarding the Spheciformes, the habitats differ in *Diodontus*, *Dryudella*, *Harpactus*, *Miscophus*, *Nitela*, *Tachytes* and *Trypoxylon* genera.

Members of all these genera are predator and provision the nests with their preys, *Diodontus* and *Harpactus* species prey on Homoptera, *Dryudella* species on Heteroptera, *Nitela* species on Psocoptera and Hemiptera, *Tachytes* species on Orthoptera, and *Miscophus* and *Trypoxylon* species on Araneae. Concerning nesting behaviour, *Dryudella*, *Harpactus* and *Miscophus* species are groundnesters, *Tachytes* members nest in pre-existing cavities like beetle burrows, *Nitela* species nest in hollow twigs or pre-existing cavities and *Trypoxylon* members nest in hollow twigs, pre-existing cavities or constructs mud nests (Ashmead 1894, Beardsley & Perreira 2000, Melo 2000, Buys 2003).

All genera are conditioned by prey abundance and adequate nesting sites (existence of pre-existing cavities, nesting plants or the soil type). This conditioned distribution is shared by other insect predators like birds and carabid beetles (Burke & Nol 1998, Guillemain et al. 1997).

The application of the Mann-Whitney U-test on all sets of data (Aculeata, Apiformes and Spheciformes) allows the establishment of differences between most of the habitats studied concerning one or several families of Aculeata (Table 11) and genera of Apiformes (Table 12) and of Spheciformes (Table 13). These families of Aculeata and genera of Apiformes and Spheciformes show specific preferences being characteristic of the habitat or habitats on which they are present, and alterations in their distribution probably indicate alterations in their habitats as was verified in previous studies (Kevan 1999). A monitorization of the Aculeata communities, namely Apiformes and Spheciformes, would provide a valuable management tool, allowing to track changes in the managed habitats and, if necessary, to adjust management actions to meet the proposed goals.

Some pairs of habitats don't show significant differences. As all sites have different characteristics and theoretically support different communities, we think that it wasn't possible to find significant differences among all the communities due to insufficient sampling and not to actual similarities between the communities.

When all sets of data are considered, only three pairs of sites don't differ consistently along all sets of data studied. This shows the importance of using the combination of these groups as they seem to act as complementary to the characterization of the habitats. This aspect of the use of two complementary indicators has been carried in studies with other invertebrate taxa in riparian areas (Smith et al. 2007).

The habitats that didn't differ consistently along all sets of data will be analyzed to explain the community similarities of Aculeata, Apiformes and Spheciformes that they support. Site pairs ALA/PFM, CAP/PFM and CAP/SDE don't differ in their Aculeata, Apiformes and Spheciformes communities.

Both ALA and PFM sites are Montados. The former a Holm Oak Montado woodland and the latter a Cork Oak Montado. The similarity in the Aculeata, Apiformes and Spheciformes communities can be related to the similarity in habitat structure as, in both habitats, the trees are very spaced with shrubland among them.

Sites CAP and PFM are quite different. While CAP is a Stone Pine stand with trees very close together forming a close canopy, PFM is a Cork Oak Montado with large spaces among trees. As previous referred, the similarities may relate to insufficient sampling.

Finally, sites CAP and SDE are both forests with one dominant tree species, *Pinus pinea* in CAP and *Eucalyptus globulus* in SDE, that have very closed canopies and consequently a low understorey vegetation diversity, which may explain the similarity of the Aculeata, Apiformes and Spheciformes communities in those habitats.

The differences found between the communities of Aculeata, Apiformes and Spheciformes of the habitats studied can be justified by the characteristics of the habitats and specific needs (food and nesting availability) of the families of Aculeata or genera of Apiformes and Spheciformes.

Regarding the Aculeata, site pairs ALA/BCP, ALA/COZ, ALA/RLM, BCP/CAP, BCP/PFM, BCP/SDE and RLR/SDE, exhibited differences relating the family Apidae.

Members of family Apidae, in general, depend on flower resources and nesting conditions, a habitat with greater moisture provides a greater variety of flower resources and a more patchy landscape provides better nesting conditions independent of specific preferences.

As seen in previous analysis, COZ is a mixed *Juniperus* woodland, providing more diverse landscape and shows a high level of moisture, being close to the Guadiana River. ALA is a Holm Oak Montado with a dominant tree species and a less diverse landscape, but an intermediate level of moisture, RLM is a shrubland being more exposed with a low level of moisture, and BCP is a fallow land, a more disturbed and exposed habitat. The lower diversity in more disturbed habitats was verified in several studies with the Aculeata (Otero & Sandino 2003, Tscharntke et al. 1998, Klein et al. 2006) and other groups like carabid beetles (Langamaack et al. 2001) and butterflies (Bobo et al. 2006).

Sites CAP, PFM and SDE are all forests with one dominant species, *Pinus pinea*, *Quercus suber* and *Eucalyptus globulus* respectively. All provide greater shading and lesser disturbance than BCP.

Site RLR is a riparian gallery with a diverse landscape and high moisture level (riverside) while SDE is a Eucalyptus plantation, very water demanding, showing a low moisture level on the soil. Riparian areas are very important for the members of the family Apidae as they provide optimal conditions and play an important role as refuges and a pollinator source for agricultural fields (Ricketts 2004).

The differences between the Apidae communities of these habitats are expected as all the sites provide very different conditions for the existence of diverse flower

resources (moisture and disturbance) and nesting conditions (patchiness) for their establishment (Patenaude 2007).

Sites ALA and COZ differed in their Mutillidae communities. Adult Mutillidae are pollinators, all are solitary and their larvae are ectoparasitoids of enclosed immatures of other insects, usually other Aculeata, but also Diptera, Lepidoptera, Coleoptera and Blattodea. Their distribution depends on the diversity of floral resources and hosts (Goulet & Huber 1993).

As referred previously, site COZ provides better conditions (moisture) than ALA for plants in general (flowering and others) which may be the food basis for Mutillidae hosts.

Sites COZ and PFM differed in their Pompilidae communities. Pompilids are spider hunters and their larvae develop on a paralyzed spider closed in a cell constructed by the female in the ground. Members of this family depend on the abundance of spiders and on soil characteristics for excavating the nest.

Site PFM is mainly a shrubland with spaced cork oak trees, the soil is more exposed to the sun and as so drier. Excavating is probably harder. On the other hand, site COZ has a closed canopy and greater moisture, as so has a softer soil and a more diverse vegetation which is synonymous of a greater insect abundance and consequently greater spider abundance (Crisp et al. 1998).

Site pairs BCP/COZ, BCP/RLR, CAP/COZ and RLM/RLR were significantly different in relation to Apidae, Crabronidae and Pompilidae families. As was referred, members of the family Apidae are pollinators and depend on flower resources. The members of the family Crabronidae are predators of several orders (insects and spiders) and depend on the abundance of their preys, and Pompilids are spider predators, depending on their abundance. As most insects are herbivores and spiders are insect predators, all families depend directly or indirectly on plant diversity which is conditioned by other factors, like moisture and soil nutrients. Besides their diet, all have also requisites regarding the nesting conditions, according to the species.

As referred before, sites COZ and RLR have greater moisture and as so a greater plant diversity. BCP, a fallow land, is a more disturbed habitat with lower plant diversity that affects directly members of the Apidae and herbivore insects, and indirectly spiders, Crabronidae and Pompilidae species.

Site CAP, a Pine Stone plantation with a very closed canopy has a low level understorey vegetation diversity, and by that has low insects and spiders diversity also. COZ has greater moisture.

Site RLM, a shrubland, has a more exposed soil with low moisture. RLR has a more shaded soil and great moisture.

Site pairs RLR/ALA and RLR/SDE differed in Crabronidae and Pompilidae families. Both families are predators, members of the family Crabronidae prey on several insect orders and spiders and Pompilids prey solely on spiders.

Sites ALA and SDE are both forest with one dominant species, *Quercus rotundifolia* for the former and *Eucalyptus globulus* for the later. RLR is a riparian gallery usually with great plant diversity. The greater plant diversity supports a greater diversity of herbivore insects and consequently of predators – spiders, Crabronidae and Pompilidae species.

Sites PFM and RLR differed in Mutillidae, Pompilidae and Tiphiidae families. Adult Tiphiidae are pollinators, all are solitary and their larvae are usually ectoparasitoids of soil-dwelling Coleoptera (Goulet & Huber 1993).

Site PFM has lower vegetation adapted to drier soil while RLR has a higher moisture and more diverse vegetation. RLR higher vegetation diversity explains the preference of pollinators (Mutillidae and Tiphiidae), predators (Pompilidae) and their hosts.

Sites CAP and RLR differed in Apidae, Crabronidae, Mutillidae, Pompilidae and Tiphiidae families.

Site CAP has a very closed canopy that influences the understorey vegetation while RLR has more diverse vegetation. RLR higher diversity probably explains the preference of all families, pollinators (Apidae, Mutillidae and Tiphiidae), predators (Crabronidae and Pompilidae) and their hosts.

Regarding the Apiformes, site pairs ALA/COZ, ALA/SDE, BCP/CAP, BCP/PFM, BCP/SDE, RLM/CAP, RLM/PFM and RLM/SDE only differed relating to the genus *Apis*.

As previously referred the only species captured belonging to this genus was *Apis mellifera* (honey bee). This species is manly “domestic” in managed hives for the production of honey. Their distribution may be more influenced by human preferences than by the species preferences (Brewer 1995).

Site BCP exhibited the highest *Apis* abundance and significant differences were found, regarding this genus, in relation to sites CAP, PFM and SDE. Site BCP as a fallow land is probably more accessible to beekeepers justifying the strong presence of *Apis*.

Site RLM showed an absence of the genus *Apis* and significant differences were found, regarding this genus, in relation to sites CAP, PFM and SDE. RLM is a shrubland, has low vegetation and greater sun exposure than CAP, PFM and SD, which are forests. This may justify the preference by beekeepers in order to protect the hives.

Site pairs RLR/ALA, RLR/BCP and RLR/CAP differed in the genus *Lasioglossum*. Members of the genus *Lasioglossum* are pollinators that usually excavate their nests in the soil and exhibit a great variety of social behaviour (Gregory & Wright 2005).

Site RLR a riparian gallery has high moisture, intermediate shading at ground level and rich soil – optimal conditions for the development of flowering plants, essential for the presence of *Lasioglossum*.

Sites ALA e CAP are forests with one dominant species, *Quercus rotundifolia* in the former and *Pinus pinea* in the later, with dense canopies and strong shading at ground level. These characteristics are less favourable for the development of flowering plants and as so for the presence of *Lasioglossum*. As for BCP, the low vegetation and high exposure at ground level makes it less favourable for the presence of *Lasioglossum*.

Site pairs RLR/PFM and RLR/RLM differed in the genus *Hylaeus*. Genus *Hylaeus* species are pollinators that usually excavate their nests in the soil and exhibit a great variety of social behaviour (Barrows 1975).

As explained previously, site RLR provides optimal conditions for the development of flowering plants and as so for the presence of pollinators in general, like *Lasioglossum* and *Hylaeus* species.

Sites PFM and RLM are both manly shrubland with low vegetation, high exposure at ground level and low moisture. These habitats are less favourable for the presence of *Hylaeus* species as they are burrowers and a dryer and harder soil is more difficult to excavate, and these habitats also have limited flowering plants, important for their presence.

Site pairs COZ/RLM and RLR/SDE were significantly different relating to genera *Apis* and *Lasioglossum*. Members of these genera are pollinators, but *Apis* is

manly “domestic” and in the wild nests in pre-existing cavities, and *Lasioglossum* doesn’t exist in “domestic” populations and excavate their nests in the soil.

Site COZ as a Mixed *Juniperus* woodland provides a greater patchiness in the habitat, differences in shading at ground level and moisture, as so is more favourable for the presence of flower plants essential for the presence of pollinators like *Apis* and *Lasioglossum*. RLM is a shrubland with great exposure at ground level and low moisture being less favourable for the presence of *Apis* and *Lasioglossum*.

Site RLR has several favourable conditions for pollinators in general yet only the genus *Lasioglossum* shows preference for this habitat, while genus *Apis* shows preference for SDE. Site SDE is an Eucalyptus plantation having limited understorey vegetation and dry soil. In general it shouldn’t be very favourable for pollinators, however the preference of genus *Apis* can be justified by beekeepers preferences.

Sites COZ and PFM differed in genera *Apis* and *Ceratina*. Members of these genera are pollinators, but *Apis* is manly “domestic” and in the wild nests in pre-existing cavities, and *Lasioglossum* doesn’t exist in “domestic” populations and nest in plant stems.

Site COZ, a Mixed *Juniperus* woodland, has different levels of shade at ground level, more moisture and so better conditions for the establishment of flowering plants. As *Apis* and *Ceratina* species are pollinators their preference would be justified by the greater plant diversity, yet only *Ceratina* shows preference for this habitat. Genus *Apis* seems to prefer PFM. This site is a Cork Oak Montado having mainly low vegetation, greater exposure at ground level and dryer conditions. In general it should be less favourable for pollinators, however the preference of genus *Apis* can be justified by beekeepers preferences.

Sites BCP and COZ differed in genera *Ceratina* and *Lasioglossum*. Members of both genera are pollinators, but with different nesting preferences. Genus *Ceratina* species nest on plant stems while *Lasioglossum* excavate their nests in the soil.

As previously referred, site COZ presents better conditions for the establishment of flowering plants. As *Ceratina* and *Lasioglossum* species are pollinators their preference would be justified by the greater plant diversity. The higher moisture in COZ also provides a softer soil for *Lasioglossum* and the greater plant diversity provides more nesting options for *Ceratina*. Site BCP is an altered habitat with low vegetation, less shading and drier soil which conditions the presence of both genera.

Sites CAP and COZ differed in genera *Apis*, *Ceratina* and *Hylaeus*. Members of all these genera are pollinators, but *Apis* exist mainly in "domestic" population and *Ceratina* and *Hylaeus* species exist in the wild, *Apis* nests in pre-existing cavities in the wild, *Ceratina* nests in plant steems and *Hylaeus* excavate their nests in the soil.

Again, site COZ provides the better conditions for the presence of all genera but *Apis* shows a preference for CAP, a pinewood plantation with great shading and limited groundcover vegetation. In general it should be less favourable for pollinators, however, once again, the preference of genus *Apis* can be justified by beekeepers preferences.

Finally, sites COZ and SDE differed in genera *Apis*, *Ceratina* and *Lasioglossum*. Yet again, site COZ provides the better conditions for the presence of all genera but *Apis* shows a preference for SDE. As previously referred SDE and CAP have limited understorey vegetation. Again, the preference of genus *Apis* can be justified by beekeepers preferences.

Regarding the Spheciformes, site pairs COZ/BCP, COZ/CAP, COZ/RLM, COZ/RLR and CAP/PFM only differed relating to the genus *Trypoxylon*. Members of the genus *Trypoxylon* are predators of spiders and nests in hollow twigs, pre-existing cavities or constructs mud nests.

Site BCP, a fallow land with greater exposure and CAP, a pinewood plantation with a shale and clay soil, both have low moisture and consequently limited vegetation diversity. On the contrary, the site COZ a Mixed *Juniperus* woodland with higher moisture, differences in shading and consequently has greater understorey vegetation diversity. This factor influences the presence of herbivore insects that are the preys of spiders, which can explain the preference of COZ site by species of *Trypoxylon*.

Site RLR a riparian gallery with the highest moisture allows a great vegetation diversity. It is even more suitable for *Trypoxylon* than site COZ.

Site pairs ALA/BCP, ALA/CAP, ALA/COZ, ALA/RLM and ALA/SDE differed in the genus *Passaloecus*. Members of this genus are predators of Aphididae and nest in hollow stems (Finnamore 1997).

Site BCP a fallow land with greater soil exposure, CAP a pinewood plantation with a shale and clay soil, RLM a shrubland also with greater soil exposure and SDE an eucalyptus plantation that is very water-demanding, all have limited moisture. Site ALA an oak wood with higher moisture than BCP, CAP, RLM and SDE, and consequently has more diverse groundcover vegetation (possibly suitable for nesting) which supports more aphids. Site COZ a Mixed *Juniperus* woodland with higher moisture and

theoretically has more diverse groundcover vegetation than ALA. But as some species of Aphididae can be pests it is possible an outbreak of the Aphididae population in ALA and consequently a greater abundance of *Passaloecus*.

Site pairs PFM/BCP and PFM/SDE differed in the genus *Nitela*. Members of genus *Nitela* are predators of Psocoptera and Hemiptera and nests in hollow twigs or pre-existing cavities.

Both, BCP, an altered habitat, and SDE, a eucalyptus stand, have limited vegetation diversity. While PFM has both low vegetation and trees, this more diverse landscape can justify the preference by *Nitela*. There is also the possibility of a greater abundance of their preys in PFM as *Quercus suber* may have some Hemiptera pests.

Site pairs RLR/BCP, RLR/CAP and RLR/SDE differed in the genera *Miscophus* and *Trypoxylon*. Members of both genera prey on spiders but *Miscophus* are groundnesters and *Trypoxylon* nest in hollow twigs, pre-existing cavities or constructs mud nests. As referred before, all these three sites have low moisture and consequently limited vegetation diversity. While site RLR is a riparian gallery with the highest moisture of all habitats considered leading to greater groundcover vegetation diversity. This factor conditions the presence of phytophagous insects that are the preys of spiders, which can explain the preference of RLR site by species of *Miscophus* and *Trypoxylon*.

Sites PFM and RLR differed in the genera *Nitela* and *Trypoxylon*. Members of both genera are predators, the former preys on Psocoptera and Hemiptera and nests in hollow twigs or pre-existing cavities, and the later preys on spiders and nests in hollow twigs, pre-existing cavities or constructs mud nests. As previously referred, *Trypoxylon* showed a preference for RLR but *Nitela* showed a preference for PFM. The preference of *Nitela* for PFM may be explained by the possibility of a greater abundance of their preys in PFM as some plant species may present great numbers of hemiptera.

Sites ALA and RLR differed in genera *Miscophus*, *Passaloecus* and *Trypoxylon*. Members of all genera are predators, *Passaloecus* prey on Aphididae and nest in hollow stems, *Miscophus* prey on spiders and are groundnesters and *Trypoxylon* also preys on spider but nests in hollow twigs, pre-existing cavities or constructs mud nests.

As referred before, *Miscophus* and *Trypoxylon* showed a preference for RLR while *Passaloecus* was more connected with ALA. Once again, an outbreak of the Aphididae population in ALA can explain the greater abundance of *Passaloecus* in this site.

It is noticeable the preference of several families of Aculeata and genera of Apiformes and Spheciformes for the riparian gallery (RLR) and the Mixed *Juniperus* woodland (COZ), giving a general idea of the ideal conditions for the development of these groups. These habitats characteristics may help to create adequate refuges in agricultural fields, for example. Riparian habitats are recognized as very important as biodiversity hotspots that can serve as refuges for species important for agriculture (both pollinators and biological control agents) (Ricketts 2004). Natural habitats in the area, like the Cork Oak Montado (PFM) an ancient agroforestry system for cork production very typical in the Alentejo and Ribatejo region (Moreira et al. 2006), and the shrubland (RLM) that is also very typical of this area, have more severe conditions supporting a lower diversity and but also a very different and equally important Aculeata, Apiformes and Spheciformes community.

FINAL REMARKS

The Aculeata, specifically Apiformes and Spheciformes, have proven to be a valid management tool to assess and evaluate habitat quality and structure. As they play important roles both in natural and agricultural systems this work suggest their utilization in agricultural systems also.

The need to minimize the impact of human activities, like agriculture, is know. Besides, some authors think that agricultural fields are as important as Protected Areas for wildlife conservation. The realization that conservation through Protected Areas alone is not enough to slow biodiversity decline, leaded to an increased focus on managed land and regulation of human activities for conservation (Tylianakis et al. 2005). Furthermore the importance of some anthropogenic habitats (namely agrarian), at a low intensity management, seems to be essential for the conservation of species that only exist in these habitats.

Half the European Union territory is cultivated. Agriculture contributed along centuries to the creation and maintenance of a variety of semi-natural habitats on which an important part of the European Union wildlife depends (1).

Based on the importance of agriculture for the maintenance of wildlife in the European Union and on the services it provides – food, medicine and primary material production, and vital ecological services, such as nutrient recycling, disease and pest

control and pollination – several authors defend the inclusion of agricultural land as Protected Areas (ICEM 2003, Bai & Penniman 2004).

Recognizing the importance of agriculture for conservation purposes in the European Union, in the Common Agricultural Policy (CAP) Reform it is clear the emphasis on environmental performance. Subsidies will be paid independently from the volume of production and will be linked to the respect of environmental, food safety and animal welfare standards. It is also anticipated the attribution of incentives to farmers that engage validated programmes to enhance environmental performance (Moreddu et al. 2004, (2)). With all this emphasis on environmental performance the active implementation of sustainable management models is imperative, being essential a constant monitoring to evaluate if the environmental plan chosen meets the goals.

Aware of the need to promote environmental protection together with economic growth and social cohesion, the Cardiff Process contemplates the integration of environmental concerns in other economic sectors. So, the development of monitoring and management tools is yet more urgent facing the future demands (CEC 2004).

The report for the Organisation for Economic Co-operation and Development (OECD) regarding agriculture, considers important to evaluate "the way wild species use different agricultural habitats" turning to the evaluation of landscape diversity, besides biodiversity.

The Aculeata are a promising tool for landscape diversity evaluation in agricultural systems (Tscharntke et al. 1998). They include pollinators of extreme importance in conservation and sustainability of agricultural systems. They also include predators, important in agricultural systems as they control potential pest species. So, their evaluation responds to the monitoring need in agricultural systems under the Common Agricultural Policy and the International Initiative for the Conservation of Pollinators, focusing on the most valued elements (Kevan 1999). With this work we tried to give some support to those demands in what concerns diversity evaluation of both agriculture and agro-silvicolous ecosystems based on some groups of Hymenoptera Aculeata.

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ANNEXES

ANNEX I

Samples → / Families ↓	ALA1	ALA2	ALA3	ALA4	ALA5	ALA6	BCP1	BCP2	BCP3	BCP4	BCP5	BCP6	CAP1	CAP2	CAP3	CAP4	CAP5	CAP6	COZ1	COZ2	COZ3	COZ4	COZ5	COZ6
Apidae	5	2	4	9	9	3	0	0	2	0	0	0	2	6	7	7	2	7	97	25	21	10	24	17
Ampulicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Sphecidae	0	0	0	0	1	0	0	0	25	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0
Crabronidae	8	5	26	10	2	2	0	0	10	3	0	0	11	3	13	1	2	1	5	3	70	35	34	15
Bethylidae	2	0	89	41	62	42	0	0	40	6	9	7	2	0	61	7	6	4	0	0	194	99	50	16
Bradynobaenidae	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chrysididae	1	0	5	0	5	5	1	1	2	0	0	0	0	0	5	0	0	0	0	0	16	10	6	4
Driinidae	0	0	2	0	2	0	0	0	0	0	0	0	13	0	10	0	0	0	0	0	20	5	23	9
Eumenidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0
Mutiliidae	0	0	7	4	10	6	0	0	7	0	3	0	0	0	1	0	0	1	0	0	153	89	95	103
Pompilidae	2	3	57	15	8	7	1	0	26	2	6	6	10	8	37	7	8	6	18	11	234	105	69	116
Sapygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tiphiidae	0	0	2	3	3	3	0	0	10	0	0	0	0	0	0	0	2	0	0	0	3	1	13	6
Vespidae	0	2	4	0	0	1	1	0	3	6	0	0	0	0	0	0	1	0	0	0	1	0	1	1

Table I-1 – Abundance values of the Aculeated hymenopterans families collected in each sampling period for each studied site.

Samples → / Families ↓	PFM1	PFM2	PFM3	PFM4	PFM5	PFM6	RLM1	RLM2	RLM3	RLM4	RLM5	RLM6	RLR1	RLR2	RLR3	RLR4	RLR5	RLR6	SDE1	SDE2	SDE3	SDE4	SDE5	SDE6
Apidae	3	2	23	0	26	17	7	3	1	0	0	0	74	11	8	3	9	13	12	8	5	2	3	5
Ampulicidae	0	0	1	0	0	0	0	0	2	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0
Sphecidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Crabronidae	0	2	93	4	25	14	0	0	25	5	8	3	34	8	46	32	27	27	0	2	17	6	4	1
Bethylidae	3	0	50	8	39	25	0	0	59	0	58	36	0	0	135	47	49	25	0	0	58	21	43	37
Bradynobaenidae	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
Chrysididae	0	0	10	0	2	0	0	0	7	1	0	0	0	0	10	4	6	4	2	1	2	0	0	0
Driinidae	3	0	0	0	2	1	0	0	5	0	2	0	0	0	48	10	205	96	2	0	6	0	2	1
Eumenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	0
Mutiliidae	0	0	8	0	0	1	0	0	5	1	2	6	0	1	22	35	34	41	0	0	9	16	6	2
Pompilidae	2	0	45	2	35	11	0	0	12	5	8	4	63	15	269	154	123	96	2	8	31	13	18	7
Sapygidae	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Tiphiidae	0	0	0	0	0	0	0	1	5	0	7	1	0	1	4	4	4	1	0	0	3	4	8	1
Vespidae	0	0	2	0	2	5	0	0	11	1	1	2	0	1	2	4	0	2	1	0	3	0	0	0

Table I-1 – Abundance values of the Aculeated hymenopterans families collected in each sampling period for each studied site. (continuation)

Samples → / Genera ↓	ALA1	ALA2	ALA3	ALA4	ALA5	ALA6	BCP1	BCP2	BCP3	BCP4	BCP5	BCP6	CAP1	CAP2	CAP3	CAP4	CAP5	CAP6	COZ1	COZ2	COZ3	COZ4	COZ5	COZ6
Andrena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	13	0	0	0	0
Anthidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Anthophora	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Apis	0	1	1	0	1	0	0	0	0	0	0	0	1	3	7	7	0	7	0	1	0	0	0	0
Ceratina	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	6	1	2	1
Chalicodoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chelostoma	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelioxys	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Creightonella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0
Dasypoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0
Duforea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucera	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7	4	0	0	0	0
Halictus	0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	3	8	9
Hoplitis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hylaeus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1
Lasioglossum	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	2	0	2	3
Megachile	0	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0
Melliturga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Nomia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Osmia	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0
Panurgus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Sphecodes	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8	0	0	0	1	3
Stelis	0	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0
Trachusa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table I-2 – Abundance values of the Apiformes genera collected in each sampling period for each studied site.

Samples → / Genera ↓	PFM1	PFM2	PFM3	PFM4	PFM5	PFM6	RLM1	RLM2	RLM3	RLM4	RLM5	RLM6	RLR1	RLR2	RLR3	RLR4	RLR5	RLR6	SDE1	SDE2	SDE3	SDE4	SDE5	SDE6
Andrena	0	0	0	0	0	0	1	0	0	0	0	0	13	2	0	0	0	0	2	0	0	0	0	0
Anthidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthophora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0
Apis	1	2	20	0	24	12	0	0	0	0	0	0	0	2	1	1	0	1	3	7	5	2	2	5
Ceratina	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	6	4	0	0	0	0	0	0
Chalicodoma	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chelostoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Coelioxys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Creightonella	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Dasypoda	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Duforea	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Eucera	2	0	0	0	0	0	5	2	0	0	0	0	20	2	0	0	0	0	1	0	0	0	0	0
Halictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Hoplitis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hylaeus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Lasioglossum	0	0	0	0	2	5	0	0	0	0	0	0	29	3	5	2	3	2	0	0	0	0	0	0
Megachile	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Melliturga	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0
Nomia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Osmia	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Panurgus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphecodes	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0
Stelis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trachusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table I-2 – Abundance values of the Apiformes genera collected in each sampling period for each studied site. (continuation)

Samples → / Genera ↓	ALA1	ALA2	ALA3	ALA4	ALA5	ALA6	BCP1	BCP2	BCP3	BCP4	BCP5	BCP6	CAP1	CAP2	CAP3	CAP4	CAP5	CAP6	COZ1	COZ2	COZ3	COZ4	COZ5	COZ6
Ammophila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Astata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bembecinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bembix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerceris	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Crossocerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Diodontus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Dolichurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Dryudella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	0
Ectemnius	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpactus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3	1
Liris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Miscophus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	18	10	9	3
Nitela	0	0	1	1	0	1	0	0	0	0	0	0	7	1	1	0	0	1	1	0	1	0	1	1
Passaloecus	7	4	3	1	1	0	0	0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0
Pemphredon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Philanthus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pison	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Prionyx	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Solierella	0	0	10	2	0	0	0	0	1	0	0	0	0	0	4	1	0	0	0	0	12	5	1	1
Sphex	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Tachysphex	0	0	0	3	0	0	0	0	6	2	0	0	1	2	0	0	2	0	0	0	14	9	6	6
Tachytes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	5	0
Tracheliodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trypoxylon	1	1	8	0	1	1	0	0	1	1	0	0	0	0	4	0	0	0	1	1	14	5	3	2

Table I-3 – Abundance values of the Spheciformes genera collected in each sampling period for each studied site.

Samples → / Genera ↓	PFM1	PFM2	PFM3	PFM4	PFM5	PFM6	RLM1	RLM2	RLM3	RLM4	RLM5	RLM6	RLR1	RLR2	RLR3	RLR4	RLR5	RLR6	SDE1	SDE2	SDE3	SDE4	SDE5	SDE6
Ammophila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Astata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bembecinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bembix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cerceris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Crossocerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diodontus	0	0	0	0	0	0	0	0	0	0	0	0	4	1	2	1	0	0	0	0	0	0	0	0
Dolichurus	0	0	1	0	0	0	0	0	2	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0
Dryudella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ectemnius	0	0	0	0	4	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Harpactus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Liris	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
Miscophus	0	0	1	0	1	1	0	0	3	0	6	1	1	0	19	12	5	6	0	0	1	0	0	0
Nitela	0	1	51	1	6	4	0	0	2	0	1	2	0	0	0	0	0	2	0	0	0	0	0	0
Passaloecus	0	0	7	0	4	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0
Pemphredon	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philanthus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pison	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Prionyx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solierella	0	0	21	1	4	1	0	0	11	5	0	0	0	0	3	3	2	0	0	0	13	3	3	1
Sphex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tachysphex	0	0	0	1	1	0	0	0	4	0	0	0	0	0	2	5	3	0	0	0	0	0	0	0
Tachytes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tracheliodes	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Trypoxylon	0	1	10	1	5	8	0	0	3	0	1	0	21	6	15	9	15	19	0	2	1	3	0	0

Table I-3 – Abundance values of the Spheciformes genera collected in each sampling period for each studied site. (continuation)

ANNEX II

	Aculeated hymenopterans			Apiformes			Spheciformes		
Samples	**S**	**E**	**H'**	**S**	**E**	**H'**	**S**	**E**	**H'**
ALA1	5	0,5173	1,365	3	0,3277	1,055	2	0,1171	0,3768
ALA2	4	0,4959	1,309	2	0,2153	0,6931	2	0,1555	0,5004
ALA3	10	0,559	1,475	4	0,4307	1,386	6	0,4658	1,499
ALA4	6	0,5399	1,425	6	0,521	1,677	7	0,5699	1,834
ALA5	11	0,5596	1,477	7	0,5869	1,889	3	0,3413	1,099
ALA6	8	0,5205	1,374	2	0,1977	0,6365	2	0,2153	0,6931
BCP1	3	0,4163	1,099	0	0	0	0	0	0
BCP2	1	0	0	0	0	0	0	0	0
BCP3	10	0,7022	1,853	2	0,2153	0,6931	6	0,2948	0,949
BCP4	4	0,49	1,293	0	0	0	2	0,1977	0,6365
BCP5	3	0,3832	1,011	0	0	0	0	0	0
BCP6	2	0,2615	0,6902	0	0	0	0	0	0
CAP1	5	0,5256	1,387	2	0,2153	0,6931	4	0,3211	1,034
CAP2	3	0,3897	1,028	3	0,3142	1,011	2	0,1977	0,6365
CAP3	8	0,5608	1,48	1	0	0	5	0,4507	1,451
CAP4	4	0,4674	1,234	1	0	0	1	0	0
CAP5	6	0,5844	1,542	2	0,2153	0,6931	1	0	0
CAP6	5	0,5191	1,37	1	0	0	1	0	0
COZ1	3	0,2232	0,589	9	0,3187	1,026	4	0,4139	1,332
COZ2	3	0,318	0,8393	8	0,4823	1,552	3	0,3413	1,099
COZ3	12	0,6159	1,625	8	0,5817	1,872	12	0,614	1,976
COZ4	11	0,6198	1,636	3	0,279	0,8979	10	0,5931	1,909
COZ5	11	0,7086	1,87	10	0,6425	2,068	12	0,679	2,186
COZ6	9	0,5628	1,485	5	0,3983	1,282	7	0,5217	1,679
PFM1	4	0,5203	1,373	2	0,1977	0,6365	0	0	0
PFM2	2	0,2626	0,6931	1	0	0	2	0,2153	0,6931
PFM3	8	0,5913	1,561	3	0,1461	0,4702	8	0,4117	1,325
PFM4	3	0,3621	0,9557	0	0	0	4	0,4307	1,386
PFM5	7	0,5843	1,542	2	0,0843	0,2712	7	0,5597	1,802
PFM6	7	0,6068	1,601	2	0,1882	0,6058	4	0,3277	1,055
RLM1	1	0	0	3	0,2474	0,7963	0	0	0
RLM2	2	0,2131	0,5623	2	0,1977	0,6365	0	0	0
RLM3	11	0,6807	1,796	1	0	0	7	0,5329	1,715
RLM4	5	0,5028	1,327	0	0	0	1	0	0
RLM5	8	0,4502	1,188	0	0	0	3	0,2285	0,7356
RLM6	6	0,4043	1,067	0	0	0	2	0,1977	0,6365
RLR1	4	0,4456	1,176	9	0,4927	1,586	5	0,3362	1,082
RLR2	6	0,5118	1,351	5	0,4953	1,594	3	0,2285	0,7356
RLR3	12	0,5752	1,518	4	0,3335	1,074	10	0,5545	1,785
RLR4	11	0,5687	1,501	2	0,1977	0,6365	8	0,5126	1,65
RLR5	10	0,5768	1,522	2	0,1977	0,6365	6	0,4101	1,32
RLR6	10	0,6353	1,677	6	0,5193	1,672	3	0,2406	0,7743
SDE1	5	0,4381	1,156	5	0,4801	1,545	0	0	0
SDE2	4	0,4245	1,12	2	0,1171	0,3768	1	0	0
SDE3	9	0,6211	1,639	1	0	0	4	0,2455	0,7902
SDE4	6	0,5901	1,557	1	0	0	2	0,2153	0,6931
SDE5	7	0,545	1,438	2	0,1977	0,6365	2	0,1747	0,5623
SDE6	7	0,4122	1,088	1	0	0	1	0	0

Table II-1 - Specific Richness (S), Evenness (E) and Diversity (H') values calculated for Aculeated hymenopterans families, Apiformes and Spheciformes genera at each sampling period for each studied site.

ANNEX III

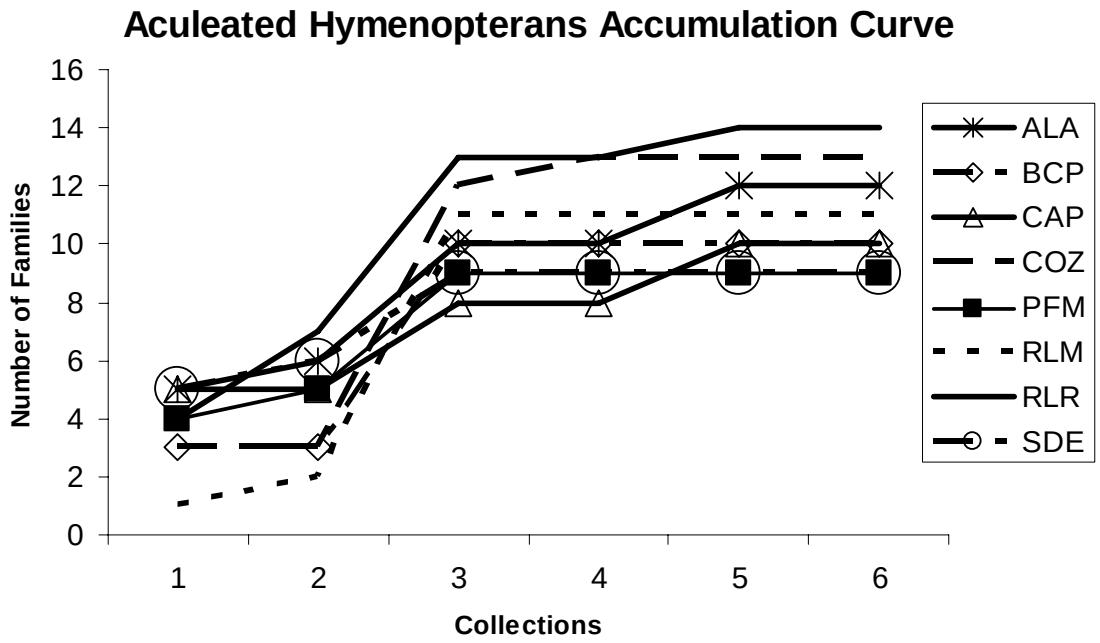

Figure III-1 – Accumulation curve of the number of Aculeated hymenopterans families, for each studied site, along the sampling period.

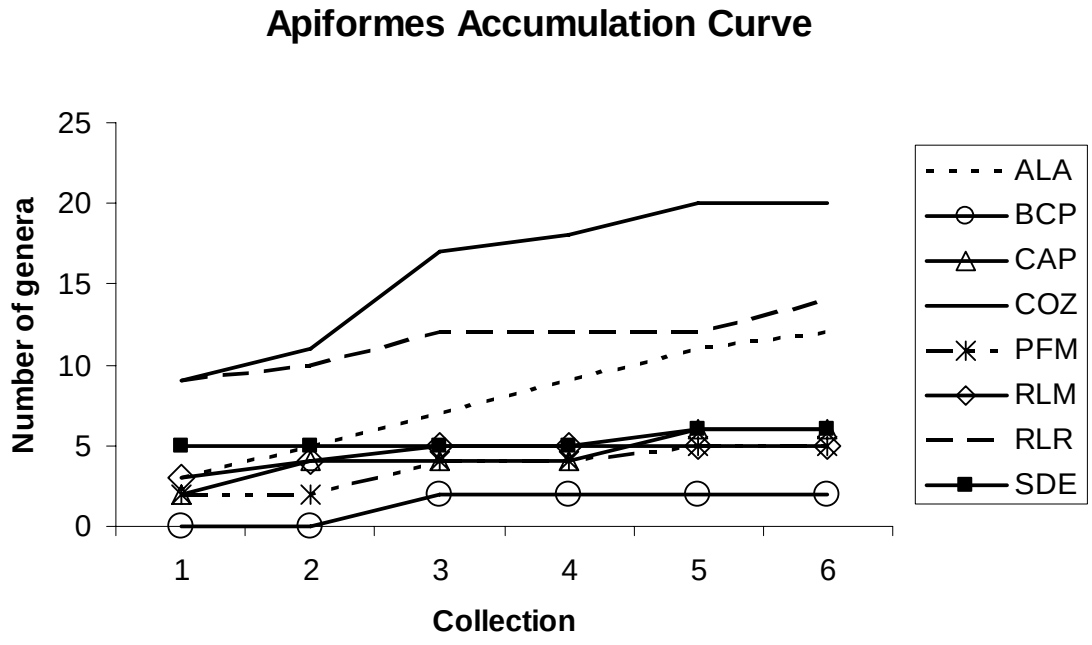

Figure III-2 – Accumulation curve of the number of Apiformes genera, for each studied site, along the sampling period.

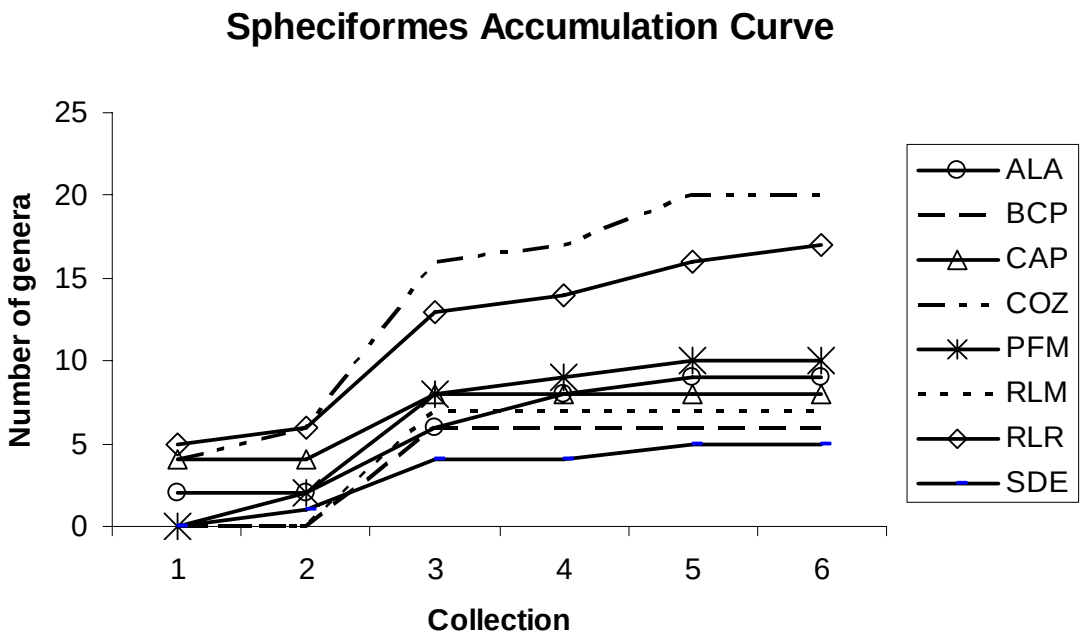

Figure III-3 – Accumulation curve of the number of Spheciformes genera, for each studied site, along the sampling period.

ANNEX IV

Family	$H_{7,48}$	p-level
Apidae	**28,565**	**0,0002**
Ampulicidae	8,135	0,3208
Sphecidae	5,106	0,647
Crabronidae	**19,403**	**0,007**
Bethylidae	3,313	0,8546
Bradynobaenidae	6,223	0,5139
Chrysididae	8,02	0,3308
Driinidae	12,093	0,0976
Eumenidae	**21,169**	**0,0035**
Mutiliidae	12,811	0,0769
Pompilidae	**24,512**	**0,0009**
Sapygidae	7	0,4289
Tiphiidae	13,455	0,0618
Vespidae	5,487	0,6008

Table IV-1 – Kruskal-Wallis One Way ANOVA results of the comparison between the Aculeate hymenopterans communities of all studied sites with indication of the calculated H and p-level. Significantly different families are signalled in bold.

Genus	$H_{7,48}$	p-level
Andrena	8,645	0,2792
Anthidium	7	0,4289
Anthophora	13,516	0,0605
Apis	**29,993**	**0,0001**
Ceratina	**28,228**	**0,0002**
Chalicodoma	6,131	0,5245
Chelostoma	6,13	0,5246
Coelioxys	6,13	0,5246
Creightonella	12,821	0,0766
Dasypoda	11,024	0,1376
Duforea	7	0,4289
Eucera	5,951	0,5455
Halictus	**19,317**	**0,0073**
Hoplitis	7	0,4289
Hylaeus	13,736	0,0561
Lasioglossum	**31,748**	**0**
Megachile	10,145	0,1805
Melliturga	7	0,4289
Nomada	8,277	0,3088
Nomia	7	0,4289
Osmia	3,293	0,8566
Panurgus	6,13	0,5246
Sphecodes	**14,482**	**0,0433**
Stelis	**17,216**	**0,0161**
Trachusa	7	0,4289

Table IV-2 – Kruskal-Wallis One Way ANOVA results of the comparison between the Apiformes communities of all studied sites with indication of the calculated H and p-level. Significantly different genera are signalled in bold.

Genus	$H_{7,48}$	p-level
Ammophila	6,13	0,5246
Astata	6,13	0,5246
Bembecinus	7	0,4289
Bembix	7	0,4289
Cerceris	8,545	0,287
Crossocerus	7	0,4289
Diodontus	**24,632**	**0,0009**
Dolichurus	8,135	0,3208
Dryudella	**21,906**	**0,0026**
Ectemnius	8,194	0,3158
Harpactus	**24,848**	**0,0008**
Liris	10,338	0,1702
Miscophus	**18,457**	**0,0101**
Nitela	**17,397**	**0,015**
Passaloecus	12,429	0,873
Pemphredon	6,131	0,5245
Philanthus	6,13	0,5246
Pison	6,357	0,4987
Prionyx	6,13	0,5246
Solierella	5,944	0,5463
Sphex	6,131	0,5245
Tachysphex	11,231	0,1288
Tachytes	**21,906**	**0,0026**
Tracheliodes	7	0,4289
Trypoxylon	**26,341**	**0,0004**

Table IV-3 – Kruskal-Wallis One Way ANOVA results of the comparison between the Spheciformes communities of all studied sites with indication of the calculated H and p-level. Significantly different genera are signalled in bold.